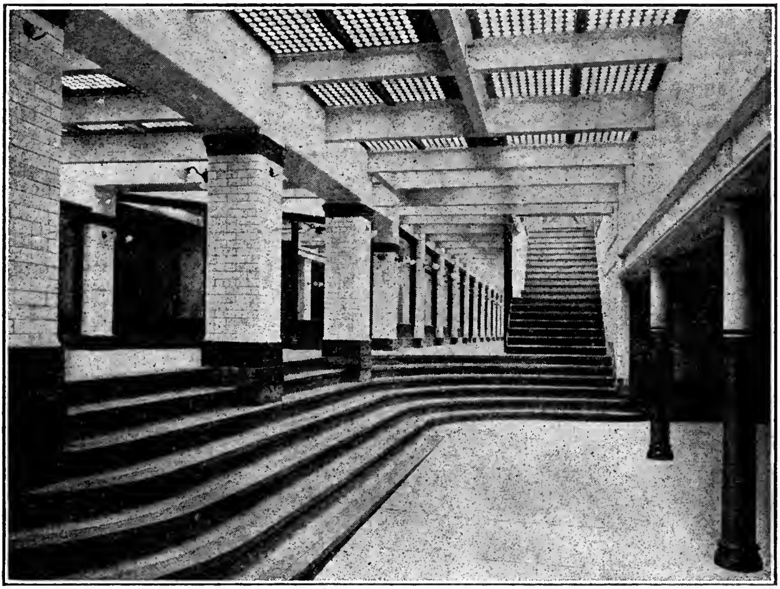

A

HAND-BOOK

FOR

CEMENT USERS

THIRD EDITION REVISED AND ENLARGED

EDITED BY

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PREFACE.

The publication of the first edition of the Directory of American Cement Industries and Hand-Book for Cement Users in 1901, was the direct result of the many demands for information upon all subjects connected with the manufacture, sale and use of cement which have been made upon Munipal Engineering Magazine, and of the conclusion, drawn from close observation, that the time had arrived for the publica- of a book giving, more particularly from the practical and commercial standpoints, the answers to all the classes of questions which those interested in cement are asking. The instant success of the book proved the correctness of this conclusion. A new edition was called for in 1902, and it was much larger and more complete than the first edition. The rapid increase in the cement trades since 1900 shows in the greatly increased number of names in the directory sections, and when the third edition of the Directory of American Cement Industries was called for in 1904, it became so large that a separation was made and the third edition of the Directory was published without the Hand-Book. An extra edition of the Hand-Book section of the second edition of the combined book was published and bound separately, and has been sold as the Hand-Book for Cement Users. On account of this extra number the third edition of the Hand-Book was not called for until the end of 1904. Advantage is taken of this opportunity to rewrite those portions of the book in which progress has been made and especially to add a full statement of the use of concrete in buildings, in solid and hollow concrete walls, in hollow cement building blocks, in floors and in various forms of reinforced concrete construction. The latter treatment is extended to bridges, arches, culverts, etc., in amplification of and addition to what has appeared in early editions.

The introductory chapter is revised in view of the great advances in the cement trade and in the uses to which cement is put. A review of these advances makes a considerable addition to the chapter.

In the chapters on testing cement, on specifications for cement and for its use, on the uses of cement and on testing laboratories, additions have been made to cover the latest developments in the technical societies, in the use of cement in public and private work, large and small, and the best new things in specifications and descriptions of methods. Some illustrations in the form of reproductions of drawings and photographs are added. While these pictures are not essentials, they aid in giving clearness to descriptions and fixing them in the memory.

A new chapter is inserted upon the manufacture of cement, giving a paper by a prominent manufacturer, with descriptions of the various methods and machinery in use in this country.

The general features of each chapter, with the above exceptions, are the same as in the first edition, and may be stated as follows:

The chapter on the uses of cement is not small, but it is not complete. The extension of the use of cement has been so rapid in the last few years that it is difficult to keep pace with it. The chapter tries to confine itself to such uses as have stood the test of time and is believed to fill the field it attempts to cover satisfactorily. It will be still further extended in future as may seem desirable.

The chapter on specifications gives samples of standard specifications for the various uses of cement which are known to give satisfaction. Variations with conditions of climate, soil, materials, etc., are shown in the difference in specifications. The author and the locality for which the specification is made are given whenever it seemed desirable.

INTRODUCTION.

The province of a Hand-Book for Cement Users is to supply for its readers practical information regarding the selection and use of cements. Theoretical considerations of the materials and methods of manufacture of cement and of the chemical changes which take place in setting are to be found in several other books, and are not of great interest to the practical worker in cement. The space which they would take is devoted to much more intimate detail of practical specifications and methods of work than will be found in other books on cement.

One of the first questions which arises is that of definitions or classification of cements. The following is as close a classification as is necessary in ordinary practice.

Those cements which are produced by burning a natural cement rock directly are all in the class of natural hydraulic cements. In such districts as Rosendale and Louisville, and in such cases as Utica, Akron, Milwaukee, Fort Scott, etc., where the name of the district is a distinguishing mark, it is added to the name of the brand.

In some cases, notably some of the factories is the Rosendale district, some selection and mixture of rocks of somewhat different composition is made, without the care and expense incident to regular chemical analysis to insure absolute uniformity and maximum quality of product. These are classed as natural hydraulic cements.

In the Lehigh region it is a common practice to improve the quality of the natural cement manufactured by adding to it inferior portions of the product of the Portland cement departments, or a proportion of the regular Portland cement where the uniformity in quality of the rotary kiln product obtains. This produces an "Improved" brand. Some of the works in the same region place upon the market second and third grades of Portland cement, some of which are made from the inferior portions of the clinker produced by the kilns and some mixtures of a portion of natural hydraulic cement with

the product of the Portland cement process. If marketed under the name of Portland cement they will be found in that list, although adulterated. The manufacturers turning out these brands are usually careful to distinguish between them in their advertising literature. Practice has changed somewhat and some factories formerly marketing several brands have reduced their regular product to one or two brands of Portland cement, not including the natural cements they may manufacture.

Perhaps the only definition of Portland cement which will fit all the American brands marketed under that name is the following: A Portland cement is made from an artificial mixture of materials containing lime, silica and alumina in proper proportions. With a very few exceptions, which are distinguished wherever necessary in this book by the word (puzzolan) in parenthesis, this definition may be restricted profitably by adding the requirement that the mixture shall be made by finely grinding the materials together and shall then be burned to a hard clinker at a high temperature. With this restriction all the American cements which have been considered as belonging to this class are included under the definition, and also those which, made from slag and lime, are treated by the Portland cement process of mixing, calcining and grinding. It is is now conceded by nearly every expert that these "calcined slag" cements may be classed as Portland cements. The definitions of Portland and puzzolan cements recommended by a commission of engineer officers of the United States Army have been accepted as the standard definitions and on the whole the most satisfactory practical statements of the differences which have been formulated. The board consists of Maj. Wm. L. Marshall, Maj. Wm. H. Bixby and Capt. Charles S. Riche, of the Corps of Engineers, United States Army. The report says:

Portland cements are products obtained from the heating or calcining up to incipient fusion of intimate mixtures, either natural or artificial, of argillaceous with calcareous substances, the calcined product to contain at least 1.7 times as much lime by weight as of the materials which give the lime its hydraulic properties, and to be finely pulverized after said calcination, and thereafter additions or substitutions,

for the purpose only of regulating certain properties of technical importance, to be allowable to not exceeding 2 per cent. of the calcined product; otherwise additions or substitutions after calcination are adulterations, necessitating a change of name.

Puzzolan cements are products obtained by intimately and mechanically mixing, without subsequent calcination, powdered hydrates of lime with natural or artificial materials, which generally do not harden under water when alone, but do so when mixed with hydrates of lime (similar materials being puzzolan, santorin earth, trass obtained from volcanic tufa, furnace slag, burnt clay, etc.), the mixed product being ground to extreme fineness.

The Corps of Engineers, United States Army, also defines natural cement as one made by calcining natural rock at a heat below incipient fusion, and grinding the product to powder.

The definition for Portland cement adopted by the International Union for Testing Engineering Materials is in accord with that given above. It is:

Portland cement is a definite designation for a hydraulic cement produced by burning an intimate natural or artificial mixture of lime with clay or other materials which contain silicates enough for combination and afterward grinding to powder, and mixtures of Portland cement with other materials are not included under the term Portland cement.

Rock from which to make natural hydraulic cement is said to have been first discovered in this country by Canvass White in 1818, when an engineer on the construction of the Erie canal. As hydraulic cement was needed on other canals, other deposits were found at Rosendale, N. Y., about 1823; Lockport, N. Y., 1824; Louisville, Ky., 1829; Cumberland and Round Top, Md., 1836; Utica, Ill., 1838, and later in Virginia and the Lehigh Valley district of Pennsylvania. Hydraulic cement was first made at Akron, N. Y., in 1840; Fort Scott, Kas., in 1868, at Milwaukee in 1875.

The development of the natural cement industry is indicated by the following statements of the amounts manufactured in various years:

Year.	No. of Works.	Product.	Value in cts. a bbl.
1880		2,030,000 bbls.	
1885		4,100,000 "	
1890		7,082,204 "	51.37
1895	67	7,741,077 "	50.32
1900	76	8,383,519 "	44.48
1901	60	7,084,823 "	43.14
1902	62	8,044,305 "	50.68
1903	65	6,930,271 "	52.28
1904	—	4,866,331 "	50.35

The general distribution of the natural cement industry over the country and the variation in price in different districts is shown by the following table for 1903:

State	No. of Works.	No. of Barrels.	Value.
Georgia	2	80,620	$ 44,402
Illinois	3	543,132	178,900
Indiana and Kentucky	15	1,533,573	766,786
*a*Kansas	2	226,293	169.155
Maryland	4	269,957	138,619
*b*Minnesota	2	175,000	78,750
Nebraska	1	....	....
New York	20	2,416,137	1,510,529
North Dakota	1	....	....
*c*Ohio	2	67,025	46,776
Pennsylvania	7	1,339,090	576,269
Texas	2	....	....
Virginia	2	47,922	25,961
West Virginia	1	....	....
Wisconsin	2	330,522	139,373

a Includes product of Nebraska and Texas.
b Includes product of North Dakota.
c Includes product of West Virginia.

The usual process in making natural hydraulic cement is to reduce the rock to kiln size by crusher or otherwise, and burn it in a continuous vertical kiln, into which it is fed in alternate layers with the coal or coke used as fuel. The product is taken out cold at the bottom of the kiln, run through crusher and cracker, and then ground between buhr stones, the fine material being separated and that refused by the screens returned to the stones for further grinding. But slight variations from this program are made, variations in plants being mainly in details of handling. Three or four natural cement plants have installed Portland cement grinding machinery. The ordinary product of the natural cement kiln is not burned so hard as is necessary with Portland cement,

so that the stone mills are ordinarily able to grind the clinker satisfactorily.

The materials used for making Portland cement are quite various. In the Lehigh region and those of the same geological horizon two kinds of rock are used. One is an argillaceous limestone making a good quality of natural hydraulic cement when burned in the ordinary kiln. The composition of this rock is very uniform in the deposits which are used for cement making and the beds are very deep, in some cases approximating 300 feet. To this rock there must be added a certain proportion of limestone, approximately 20 per cent., to produce the proper mixture to stand the high heat of the kilns and produce a true Portland cement. These materials are mixed and ground, the composition of the two kinds of stone being watched very closely that necessary changes may be made in the proportions. There is an occasional deposit of cement rock which is so near the correct composition and so uniform that but one kind is used. Gradual reduction by rock crushers, crackers and mill stones, Griffin mills, or ball and tube mills, is the rule.

The powdered stone from the grinding mills is moistened being dried thoroughly by hot air. There are a few modified tr. and made into bricks when burned in vertical kilns, the bricks Shofer, Johnson, and Dietzsch continuous kilns in use and a very few dome kilns. When the latter kiln is used the cold kiln is filled with alternate layers of the bricks of slurry and the coal or coke used as fuel. The kiln is then ignited and kept burning until the fuel is consumed. The amount of fuel to produce the proper degree of calcination must be determined before hand. When the kiln has had time to cool, the clinker is taken out, carefully sorted and the good material sent to the crusher. Counting the time for sorting and cooling the kiln, the capacity of the intermittent kiln is about 25 barrels of cement a day when well managed, and it requires fuel amounting to 25 per cent. or more of the weight of cement produced. The continuous vertical kilns for burning Portland cement must be capable of attaining a much higher temperature than the ordinary lime or natural cement kiln. The various patterns produce the same effect in somewhat

similar manner to the Shofer kiln. It is three stories in height. The slurry bricks are put into the kiln on the upper floor through charging doors at the foot of the stack. The heat arising from the combustion below thoroughly dries the bricks and heats them. The fuel is put in through stoke holes on the floor below, and may be of the cheaper kinds of coal. The combustion takes place in a section of the shaft which is very much less in cross section than either above or below, that the draft may be concentrated and the heat as intense as necessary. The clinker is removed below from an enlarged section of the kiln, and as it is removed the material above drops down, thus making the action of the kiln continuous. The draft of air for the fire being through the hot clinker, serves to cool that material and itself becomes heated and thus aids combustion. These kilns are economical of fuel, requiring about 12 per cent. of the weight of the cement product in coal. They may be run as high as 75 barrels of cement a day. The product is more uniform than with the intermittent kiln, but still requires careful selection, as the process is not absolutely under the constant control of the operator.

The rotary kiln was invented in England, but was made successful in this country. In the Lehigh region the powdered stone, having been thoroughly dried before grinding, is fed into the upper end of the rotary kiln, which is a steel cylinder, lined as necessary, about 6 feet in diameter and from 50 to 75 feet long, depending somewhat upon the form of the material to be burned, revolving slowly. It is set on a slight incline so that the raw material gradually runs to the lower end. Powdered coal is now almost exclusively used as fuel, unless natural gas is available, being forced under pressure into the lower end, where it burns at the point of entrance. The force of blast, amount of fuel, and rate of rotation of the cylinder being under the instantaneous control of the operator, the character of the product depends entirely upon his attention to the work, and practically every particle of the resulting clinker makes the highest grade of cement of which the material is capable. The rotary kiln burns in fuel a little more than one-third the

weight of the cement produced, and kilns are made capable of turning out 100 to 150 or even 200 barrels of cement a day. The effect of this kiln upon the development of the cement industry is considered later.

The tendency is toward longer kilns, especially in the wet process mills, described below, which must evaporate the large quantities of water used in making the mixture, and they will be found of various lengths, even exceeding 100 feet in a few instances. One kiln in a dry process mill is 150 feet long and is served with fuel by two or three feeder tubes under different air pressures, so that the combustion zone is extended for a greater distance along the kiln. This largely increases the capacity of the kiln, claims of 1,000 barrels a day being made.

The clinker may be run through crushers and crackers if large enough to need it. That from rotary kilns is, however, so small, say the size of peas or a little larger, that this is not necessary. A few mills use buhr-stones for grinding, but most Portland cement clinker is too hard to grind economically in this manner. The Griffin mill, an American invention, consists of a steel ring, against the inside surface of which a heavy steel roll revolving on a vertical shaft presses by centrifugal force. A separator drops the fine material into conveyors for transfer to the stock rooms and returns the coarser material to the mill for further grinding. Other mills on similar principle but differing materially in design are entering the field. The ball mill is approximately a cylinder partly filled with steel balls or round pebbles of very hard stone and arranged with screens for separating the fine product and returning the coarse product to the mill. It was originally used in the same manner as the other mills mentioned, but is now generally used as a first reducer, the material, when it is reduced to the required size, passing to a tube mill, which has a continuous cylindrical surface and is much longer. The material passes slowly from one end of the mill to the other. The size of the particles of clinker fed to the tube mill, the amount of pebbles with which it is charged, the rate of rotation and the length of the tube are variable quantites, the resulting design in any particular case giving a uniform fineness of product. The crushed clinker from the ball

mill is fed into the tube mill through the axis at the upper end and drops out at the circumference or the axis as desired at the lower end. If the mill is properly designed, a separator to return partly ground material is not necessary. There are also closed pebble mills into which the material to be ground is introduced in charges, each charge being run a definite length of time, as determined by experience. The finely ground material is then removed and a new charge put in. With any of the apparatus mentioned any desired degree of fineness can be secured. The particular apparatus to be used, and the length of time the material must be retained, depend upon the hardness of the material, the fineness desired and the cost of operation allowable.

In some factories the raw materials are limestone and clay or shale, which may be treated by the dry or the semi-wet processes already described.

In most of the factories of Ohio, Indiana and Michigan the wet process of mixing the materials or some modification of it is used. The marl is excavated from the lake or marsh at the bottom of which it has been deposited by nature and is pumped or otherwise conveyed to a bin or basin in the factory. The clay or shale is brought in from the bank and the two materials are mixed in edge runner mills with water enough to allow the mixture to flow into another basin and be pumped through wet grinding mills, and kept moving in tanks, where it is analyzed and the mixture corrected. Thenec the wet material is pumped into the upper end of rotary kilns similar to those mentioned above, dropping out at the lower end as well burned Portland cement clinker. The process of mixing varies somewhat in different mills, but is in principle that followed in the best European plants.

One or two factories in this country use chalk and clay.

The manufacture of a cement from blast furnace slag is a recent development in this country. Several factories are now taking the slag from furnaces using suitable ore, cooling it suddenly with water and mixing the resulting slag sand with limestone or lime. The materials are thoroughly dried and mixed and then pulverized and fed to a rotary kiln according to the dry process. The resulting clinker is ground and pro-

duces a cement with similar constituents and characteristics and made by a similar process to other American Portland cements, so that it can not be excluded by definition of process or product from the list of Portland cements.

Several factories are producing a cement properly classed as puzzolan by mixing blast furnace slag, prepared as described, with slaked lime and grinding to the desired fineness. Although often sold under the name of Portland cement and avaliable for many of the same processes, it is not a true Portland cement according to the accepted definitions given. The spelling of the word puzzolan has been changed from that used in the first edition of this book, for, although the form pozzuolana shows its derivation most clearly, the adoption of the shorter form by the Corps of Engineers, United States Army, and by prominent manufacturers, as well as the tendency of our language toward the shortest forms possible, makes the latter the more desirable.

A few factories are making cement by a special process consisting in the intimate mixture of dry sand and cement followed by very fine grinding, so that the result is an impalpable powder composed of cement and sand. Tests of proper materials, very finely ground, show some surprisingly high results for tensile strength, and briquettes on long time tests sometimes show higher results than the neat cement from which the mixture was made. These cements are called silica cements. The tendency to cheapen the cement is observed in some of these brands as in other brands of Portland cement, but there are a few brands of silica Portland cements which have a deservedly high reputation for strength and uniformity, especially in tests of mortar briquettes.

A short statement of the principal reasons for the enormous development of the American cement industry may be of interest. It is largely due to two causes. One is the increase of density of population and the consequent increase in the amount of work in which cement has long been used and in the great extension in the number of uses to which cement can be put; and the other is the development of laborsaving processes for manufacture which reduce the cost, so that cement can be used for many constructions from which

it has been largely excluded on account of the relative cheapness of other materials.

The intermittent vertical kiln, similar to the lime kiln, was first used in burning natural cement, perhaps as early as 1823, in this country. It was soon followed by the continuous kiln, of similar type, but with more than double the capacity, because no time was lost in cooling the calcined material and recharging and refiring the kiln. The comparatively low temperature in these kilns is sufficient for the calcination of the natural cement rock; in fact, a higher temperature injures the product from some deposits of cement rock.

The Portland cement industry developed in other countries, notably in England, France and Germany, using chalk or limestone and clay as materials. Intermittent kilns like the dome kilns, continuous kilns like the Dietzsch, and ring kilns like the Hoffman, were used, the high temperature necessary for complete calcination of the exact mixture necessary for Portland cement being obtainable in the special combustion chambers or by the methods of charging and burning. With the very best of care, however, it was impossible to secure uniform calcination of all the products of the furnace, and very careful selection of clinker was necessary that the cement be uniform. This necessitated much hand labor with a certain expertness, and with the vast amount of labor necessary in making bricks, drying them and depositing them in the kiln and the many handlings between, made a total which, under American conditions of labor, insured a price too high to compete with cement produced with the cheaper labor of Europe.

Notwithstanding this and the entire difference in materials, Mr. D. O. Saylor conceived the idea of making Portland cement by European methods, modified to make them fit the materials he had, viz.: the natural cement rock of the Lehigh region and limestone. After years of experimenting he succeeded in making a high grade of Portland cement by mixing the two kinds of rock in proper proportions, and by introducing labor saving devices and improved machinery was able to compete in the American market with foreign cements, with some help from the tariff, except where the prejudice in

favor of foreign cement at any price could not be overcome.

Ten years after Mr. Saylor made his first Portland cement Ransome patented in England and the United States the rotary kiln, using gas for fuel, but with the small kilns used and the previous treatment of raw material it was a failure. The Atlas Portland Cement Company took up the kiln, and with the more favorable hard and dry materials of the Lehigh Valley, finally made a success of it. Crude oil was later introduced for fuel, which is now almost entirely displaced by finely powdered coal.

Mention should be made of earlier use of the kiln with reasonable success by Duryee and Sanderson at Montezuma and Wallkill, N. Y., in works which are not now in operation, owing to excessive cost of raw materials in one case and to destruction of the works by fire in the other.

With the success of this kiln the development of the Portland cement industry in this country began in earnest. It is possible to carry the material from the raw material cars to the finished package of cement without any handling, and this great reduction in the cost of labor enables the American manufacturer to compete successfully in price with any country in the world.

In 1892 the Warner Portland Cement Company tried the perfected kiln upon wet slurry, obtained by the mixture of marl and clay in pug mills, instead of drying and pulverizing bricks made of it and attempting to calcine this dust according to the method which failed in England. This was successful, and the development of the manufacture of cement in northern Ohio and Indiana and in Michigan is due to this process, the wet material fed in at one end of a rotary kiln coming out at the other perfectly calcined Portland cement clinker of the size of peas. The Sandusky Portland Cement Works, under the management of the Newberrys, are responsible for much of the progress made toward technical perfection in cement manufacture.

One feature of the rotary kiln process is the absolute uniformity with which the clinker can be calcined. The introduction of variable speed apparatus puts the kilns under the absolute control of the expert in charge of them, and he can

determine exactly the rate and amount of calcination the material shall receive.

The capacity of the rotary kilns in use averages about 125 barrels a day, say six times the capacity of the old intermittent kiln. They require more than twice the fuel of the continuous vertical kiln per barrel of product, so that there is some offset to the saving in labor cost.

Another branch of the process in which there has been great improvement is the grinding of clinker and, where required, of the dry raw materials. There are two general classes of mills; those in which the fine dust is separated from the partly ground material, the latter being returned to the mills; and those in which the process is continued long enough to turn out the finished product of any desired degree of fineness.

The amount and the rapidity of the development of the manufacture of Portland cement in the United States are indicated by the following figures from the reports of the United States Geological Survey:

Year.	No. of Works.	Product, Barrels.	Value. *
1880		82,000	
1885		150,000	
1890	16	355,500	$ 704,050
1895	22	990 324	1,586,830
1900	50	8,482,020	9,280,525
1901	56	12,711,225	12,532,360
1902	65	17,230,644	20,864,078
1903	78	22,342,973	27,713,319
1904	—	26,505,881	23,355,119

*The value includes packages in 1900. Later figures give value in bulk.

The distribution of the manufacture of Portland cement and the development in the various regions is shown in the following table:

District.	1890			1894			1900			1903		
	No. of W's	Prod't Bbls	Per Ct.	No. of W's	Prod't Bbls	Per Ct.	No. of W's	Prod't Bbls	Per Ct.	No. of W's	Prod't Bbls.	Per Ct.
New York	4	65,000	19.4	4	117,275	14.7	8	465,832	5.5	12	1,602,946	7.2
Lhigh and Northampton Co's Pa. & Warren Co. N.J.	5	201,090	60.0	7	485,329	60.8	15	6,153,629	72.6	15	12,324,922	55.2
Ohio	2	22,000	6.5	4	80,653	10.1	6	534,215	6,3	8	729,519	3.3
Michigan	......	....	......	......	....	......	6	664,750	7.8	13	1,955,183	8.7
All Other Sections,	5	47,500	14.1	9	115,500	14.4	15	663,594	7.8	29	5,730,403	25.6
TOTAL,	16	335,500	100.0	24	798,757	100.0	50	8,482,020	100.0	78	22,342,973	100

The principal materials used are the mixtures of cement rock or clay and limestone and the mixtures of clay and marl.

All the new factories have installed rotary kilns. The amount of cement made in other kinds of kilns has been reduced somewhat by closing of some such kilns and the replacing of others by rotary kilns. The complete displacement of all other kilns is but a question of a comparatively short time, with the exception, perhaps, of a very few special cases.

Puzzolan or slag cement in 1903 was made in seven plants in six states, Alabama having two plants under one management, and Illinois, Maryland, New Jersey, Ohio and Pennsylvania one each. Another plant in Ohio began operations in 1904. There are several other plants using slag and limestone for making a true Portland cement.

The expansion in the use of cement and the fact that cement is in reality a cheap material for its weight and bulk, increase the tendency toward localization of the industry and the new plants are using the best materials they can find, without much reference to whether they are two kinds of stone, stone and clay, marl and clay, etc. Since 1899, Alabama, Colorado, Georgia,

Indiana, Kansas, Missouri, Texas, Virginia and West Virginia have been added to the list of states in which Portland cement is manufactured, and New Mexico and North Dakota have been taken off. Neither of these states should have been on the list, for the New Mexico plant makes plaster and the North Dakota plant makes natural hydraulic cement. In the same time the number of works in California has increased from 1 to 3; in Illinois from 2 to 5; in Michigan from 4 to 13; in New Jersey from 2 to 3; in New York from 7 to 12; in Ohio from 6 to 8; in Pennsylvania from 9 to 17.

The increase in the manufacture of cement in the various states from 1899 to 1903 is shown in the following table:

PRODUCTION OF PORTLAND CEMENT IN THE UNITED STATES IN 1899 AND 1903:

State.	1899			1903		
	No. of works	Product.	Value, not including packages.	No. of works,	Product.	Value, not including packages.
		Barrels			*Barrels*	
Alabama	.....	....	....	* 1	....	....
Arkansas	1	50,000	$87,500	* 1	....	....
California	1	60,000	120,000	3	631,151	$1,019,352
Colorado	.....	....	....	* 1	258,773	436,535
Georgia	.....	....	....	* 2	....	....
Illinois	2	53,000	79,500	5	1,257,500	1,914,500
Indiana	.....	....	....	3	1,077,137	1,347,797
Kansas	.....	....	....	* 1	1,019,682	1,285,310
Michigan	4	342,566	513,849	13	1,955,183	2,674,780
Missouri	.....	....	....	* 2	825,257	1,164,834
New Jersey	2	892,167	1,338,250	3	2,693,381	2,944,604
New York	7	472,386	708,579	12	1,602,946	2,031,310
Ohio	6	480,982	721,473	8	729,519	998,300
Pennsylvania	9	3,217,965	4,290,620	17	9,754,313	11,205,892
South Dakota	1	35,000	70,000	* 1	....	....
Texas	.....	....	....	* 2	....	....
Utah	1	45,000	135,000	* 1	....	....
Virginia	.....	....	....	* 1	538,131	690,105
West Virginia	.....	....	....	* 1	....	....
Total	36	5,652,266	8,074,371	78	22,342,673	27,713,319

* In 1903 the production for Alabama, Georgia, Virginia and West Virginia is combined under Virginia, and is a clear gain of five plants over 1899, since none of these States had plants in operation in the earlier year. Arkansas and Missouri are combined under Missouri in 1903, so that the one plant of 1899 with 50,000 barrels capacity has expanded to 3 plants with 825,257 production. Kansas and Texas are combined under Kansas, a clear gain of three plants over 1899. Utah, South Dakota and Colorado are combined under Colorado and show a gain of one plant over 1899.

The following table, giving the total consumption of cement in the United States, will also be of interest, showing at it does the development in each case of the classes of cement reported and the effects of the changes in conditions upon the cement trade. The per cent. of the total cement used during the year for each kind is also given. The percentages have been computed from the quantities given in reports of the United States Geological Survey and the Bureau of Statistics of the Department of Commerce and Labor. The figures for imported Portland and for domestic Portland are corrected for the amounts re-exported and exported, respectively, for the last three years, thus showing the actual consumption of cement in the United States. Exports prior to 1901 and puzzolan manufacture prior to 1899 were small enough to be neglected.

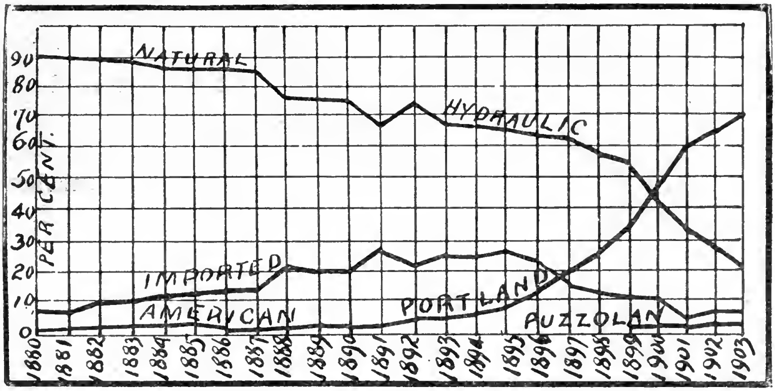
TOTAL CONSUMPTION OF CEMENT IN THE UNITED STATES IN BARRELS AND ANNUAL PERCENTAGES OF EACH CLASS REPORTED.

Year.	Natural Hydraulic.	Per Ct. for Yr.	Imported Portland.	Per Ct. for Yr.	Domestic Portland.	Per Ct. for Yr.	Puzzolan.	Per Ct. for Yr.
To 1880	54,970,000	98.4	793,281	1 4	82,000	0 2		
1880	2,030,000	89.9	187,000	8 3	42,000	1.8		
1881	2,440,000	89.7	221,000	8.1	60,000	2.2		
1882	3,165,000	87.4	370,406	10.2	85,000	2.4		
1883	4,190,000	87.9	486,418	10.2	90,000	1.9		
1884	4,000,000	85.4	585,768	12.5	100,000	2.1		
1885	4,100,000	85.4	554,396	11.5	150,000	3.1		
1886	4,186,152	84.0	650,032	13.0	150,000	3.0		
1887	6,692,744	83.5	1,070,400	13.4	250,000	3.1		
1888	6,253,295	75.0	1,835,504	22.0	250,000	3.0		
1889	6,531,876	76.2	1,740,356	20.3	300,000	3 5		
1890	7,082,204	75.7	1,940,186	20.7	335,000	3.6		
1891	7,451,535	68.4	2,988,313	27.4	454,813	4.2		
1892	8,211,181	73.3	2,440,654	21.8	547,440	4.9		
1893	7,411,815	69.5	2,674,149	25.0	590,652	5.5		
1894	7,563,488	68.7	2,638,107	24.0	798,757	7.3		
1895	7,741,077	66.0	2,907,395	25.6	990,324	8.4		
1896	7,970,450	63.7	2,989,597	23.9	1,543,023	12.4		
1897	8,311,688	63.5	2,090,924	16 0	2,677,775	20.5		
1898	8,418,724	59.6	2,043,818	14.3	3,692,284	26.1		
1899	9,868,179	55.3	2,108,388	11.8	5,652,266	31.6	233,000	1.3
1900	8,383,519	42.7	2,386,683	12.2	8,482,020	43.2	365,611	1.9
1901	7,084,823	34.4	893,444	4.3	12,337,291	60.0	272,689	1.3
1902	8,044,305	29.5	1,926,704	7.0	16,889,823	61.8	478,555	1.7
1903	6,930,271	21 8	2,225,272	7.0	22,057,510	69.5	525,896	1.7
1904	4,866,331	15.2	1,059,666	3.3	25,730,941	80.5	305,045	0.9

The data in this table are shown graphically in the accom-

panying diagram. The vertical ordinates represent the percentages of each cement used in a year, computed on the basis of the total amount of the four classes used in a year, and the diagram represents these percentages for each year from 1880 to 1903.

DIAGRAM SHOWING CHANGES IN PERCENTAGES OF THREE CLASSES OF CEMENT USED EACH YEAR FROM 1880 TO 1903:



The following table shows the increase in consumption of cement per capita of population. It is computed from the preceding table of total consumption of cement in the United States, assuming 380 pounds as the net weight of Portland cement, 280 pounds as the average net weight of hydraulic cement, east and west, and 330 pounds as the net weight of puzzolan. This may be compared with the statement that in 1900 the average production of Portland cement in Germany, was 135 pounds per capita:

CONSUMPTION OF CEMENT IN THE UNITED STATES.

Per Capita of Population.

Year.	Population.	Consumption in Pounds Per Capita.	
		Portland Cement.	All Kinds of Cement.
1880	50,155,783	1.7	13.1
1890	62,622,250	13.8	45.5
1900	75,559,258	54.7	87.3
1904	80,734,061*	126.1	144.3

* Estimated.

The exportation of cement is increasing with modifications caused mainly by the differences in ratio of home supply and demand. The exports for 1896 were 85,486 barrels; for 1900, 139,939 barrels; in 1902, 375,130; in 1903, 312,160; and in 1904, 774,940. In each case these figures include domestic cement exported and foreign cement re-exported.

The following data regarding average product of each mill and average value per barrel at the mill, will be of interest. The table to 1901, is taken from Municipal Engineering, Vol. XXIV, page 83; the figures for 1902 and 1903 being added as computed from the cement reports for those years made by the United States Geological Survey. In computing the daily product from the annual product, the operating year is assumed as 300 days:

AVERAGE PRODUCT PER MILL AND AVERAGE VALUE OF PORTLAND CEMENT AT MILL.

Year.	Average Product of each Mill. Barrels per day.	Average Value in bulk, per Barrel at Mill
1895	150	$1.60
1896	197	1.57
1897	308	1.61
1898	397	1.62
1899	523	1.43
1900	565	1.09
1901	757	.99
1902	912	1.21
1903	955	1.24

It is probable that the number of mills in operation in 1904 has been no greater than the number in 1903 and that the average production per mill is somewhat greater. The value per barrel at the mill was but 88 cents during 1904.

In Canada in 1904 the output of natural hydraulic cement decreased to 56,814 barrels as compared with 92,252 barrels in 1903. In 1904, 908,990 barrels of Portland cement were manufactured, a material increase over 1903. The imports of cement were 784,630 barrels of 350 pounds in 1904, the value being $1,061,056. The United States supplied more than half of this or $510,718 worth.

THE MANUFACTURE OF PORTLAND CEMENT.

The following from a paper before the International Engineering Congress at St. Louis, Mo., in October, 1904, by Robert W. Lesley, Assoc. Am. Soc. C. E., is a clear description of the principal methods of manufacturing Portland cement and of the principal kinds of machinery used therein:

Power.—Economies in this field are at the root of the whole business, and all modern mills for the production of Portland cement depend largely upon cheapness in the production of the power operating the machinery.

To produce cement properly at a reasonable cost, mills must have large capacity and turn out many thousands of barrels per day. This can only be done with the most improved steam-producing machinery and the most economical method of distributing the power throughout the plant. An examination of cement mills, the world over, will disclose the fact that, in all those of large size in successful operation, the steam plant represents the highest development of power-producing machinery.

Power must be produced in the most economical way, and no form of economical steam production can be neglected, if the manufacturer desires to keep pace with his rival. Boilers of the most improved character, and engines of the most modern form are to be found in cement mills of the kind described.

Coupled with all these developments is the simplest form of distributing the power. The present period marks the introduction of large and powerful shafting, driven with the shortest length of belting, or rope drives, directly from the engines, and transmitting the power to crusher mills, kilns and other parts of the machinery with the least possible friction.

Further than this, the great development of electricity has enabled numerous companies to operate much of, and in many cases all, their machinery by independent motors of various kinds. This is very successful where the water power is near the mill, as is the case with some of the Michigan mills, and is also likely to be the case with some of the European mills to be constructed in Switzerland and northern Italy. It is also practicable where cheap power may be obtained by the use of waste from iron furnaces, as is the case with the new works which the Illinois Steel Company is building at Buffington,

near near Chicago, Ill. At this plant waste heat from the iron furnaces is to be used to produce power, which, in turn, is changed to electricity and transmitted by heavy cables, over the Calumet river, some eight miles to the new works.

There is considerable discussion among the leading manufacturers and experts as to the relative cost of the electrical power produced by steam and steam power, though the general opinion is in favor of the latter; it being considered that, while single motors, driving single machines, enable kilns and mills to be thrown in and out of gear with greater economy than where belting is used, yet this advantage does not over-balance the greater cost of production of electricity, even though in the former method the loss of power by friction in shafting and belts is admitted as a disadvantage.

Raw Materials.—The raw materials for cement making include the great number of substances containing lime, silica and alumina. Consequently, they may be said to exist the world over, but the successful establishment of a Portland cement plants depends, not only upon the raw materials, but upon their juxtaposition to each other and to proper fuels, and upon proper railway facilities for the distribution of the product to the markets where it is to be consumed.

Limestones, argillaceous limestones, cement rocks, and marl, are among the cement-making materials, and all may be said to contain the lime element. To all these, except the cement rocks, silica and alumina, in the form of clay or shale, are added to produce the argillaceous or clayey requirements, while, to the cement rocks, additional lime is added to bring the material up to the proper lime limit.

Every mill has, for its basic proposition, the proper governing of these raw materials, and their proper preparation for calcination. At this point occurs the first dividing line in the industry. The manufacturer must produce the material for calcination from either wet or dry mixtures. If the raw material is a marl, or a substance of that character, he will add clay or shale to bring it up to the proper and required argillaceous composition. As the lime material is wet, the mixture of clay in this slurry will be a wet one. This position, governed by the selection of raw materials for manufacture, must govern the first process, namely, the preparation of the raw materials for the kilns; and this selection will govern the machinery for all the processes, up to the introduction of the wet slurry, or composition, into the kiln, whether dome kilns, continuous kilns, ringofen or rotary kilns are used.

Mining the Raw Materials.—The kind of raw materials, either dry or wet, having been decided, the problem now pre-

sented to the manufacturer is to procure and deliver it at the place for its preparation. In the case of marl and clays, there are many methods in use. Marls, where semi-dry, may be excavated by hand labor or steam shovels. The material is carried to the "raw" or "composition" side of the cement mill in barrows or carts. Where the material is very wet marl, as in many of the Michigan and Indiana plants, where it lies at the bottom of lakes, it is excavated by dredges. Clays are excavated either by steam shovels or by hand.

Rocks and shales are mined in open quarries or in tunnels. Most of the cement quarries are open-faced, and the methods are those used in ordinary limestone quarries. Steam, compressed air, or electric drills are used for making the holes preparatory to blasting, and, in most operations, the material is delivered at the composition side of the mills by cars or carts. In some of the more modern mining operations steam shovels are substituted for ordinary labor, and the rock, as it is blasted, is picked up and conveyed by the steam shovels to cars or carts; but this is practicable only when the material is very uniform in analysis. In mining the limestone requisite to bring cement rocks up to proper composition, the practice is similar.

Shale is mined either in accordance with the practice of dealing with clays, where the material is soft, or is handled or mined by processes similar to those used in quarrying limestone when the shale is hard.

At this stage the elements of vital importance consist in procuring only materials of proper character, and in classifying them properly, as well as in developing the most economical methods of mining the raw materials and delivering them to the mixers or dryers.

Preparation of the Raw Materials.—In modern practice it is considered not only necessary to have continuous analyses of the cement rocks, limestones, marls, clays, etc., made as they are being mined, but also to have at the plant, on the composition side, sufficient quantities of materials on hand to check up these analyses, and also to have stock to meet any unexpected break-down in the mining machinery, or delays caused by storms or other reasons. Therefore, stone storage buildings are found in connection with the most modern mills, and in some cases these edifices are warmed by waste heat, so that the external moisture upon the stones or clays may be expelled even before the drying process.

Drying the Raw Materials.—After assembling the materials, the line of demarcation between wet and dry processes becomes fixed. Wet substances, clay and marl, are handled in the condition in which they come from the marl beds or clay pits, and,

after being proportioned by weight, are run into mixers of various forms, as described later. In some cases it has been found advisable to add the clay to the marl at a later stage in the process, and in this case it is dried in rotary dryers of various forms, such as the Cummer dryer, Ruggles-Coles Company dryer, Mosser dryer, or similar apparatus. The general principle is that of a long cylinder, which revolves in a chamber of brick at one end, wherein a coal fire is placed. In this case the clay, when dry, is pulverized and introduced into the wet marl by weight, in exact proportions, in order that the mixture may be combined properly.

Dry material, limestones and cement rocks, are first crushed in the well-known forms of Gates gyratory crushers, or in Blake crushers, in which they are reduced to small pieces.

After this operation, the crushed material is placed in dryers in order to eliminate any surface moisture or moisture contained in the rock. In general practice, the mixture of the dry materials takes place at the crusher mouth, and at this point is placed a furnace scale, with a number of beams, set to weigh the various ingredients. After weighing the material it is placed in a crusher, in which a preliminary mix takes place. A variation from this process is found in certain works, where the two materials are mixed at a later stage in the process, namely, after they are ground raw, and in this case they are brought together in a powdered form, after weighing and proportioning by any of the well-known forms of automatic weighing apparatus.

Wet materials are generally mixed by weight, and, except where clay in the dry form is added, this takes place before the first grinding.

Crushing and Grinding the Raw Materials.—In the case of wet raw materials, practice varies, both in the United States and in Europe, depending upon the character of the substances. If the marl and clay are free from grit, sand or shells, they can be mixed intimately in pug mills, or wash mills, and the mixture stored in a very wet condition in tanks. When the materials contain grit, or shells, modern practice requires wet grinding, usually by mills of the ordinary buhr-stone type. Numerous forms of these have been in use. Revolving pans and chasers may also be used. The character of the raw material and its homogeneity being the governing factor in the product, it may be stated that, even where the materials are extremely uniform in character, modern practice prefers to grind them, rather than trust to ordinary mixing in tanks or pug mills, as above stated.

After the raw wet material has been prepared by any of

these forms of machinery, in modern plants it is usually placed in one of a series of tanks, having proper means for agitating the "mix" and keeping it of the right consistency. Samples from these tanks are analyzed, to govern the character of the composition, and if satisfactory, it is then made into bricks, blocks, or other forms, where dome kilns or continuous kilns are use; or, if rotary kilns are used, it is run into smaller tanks above the kilns. In either case, homogenizing tanks are required, wherein the mixture may be run if not of satisfactory character, and wherein it may be treated by adding and mixing in the requisite ingredients.

In the case of dry materials, the preliminary grinding is one of the most important features, especially where the material is to be used in rotary kilns. The character of the resultant clinker and cement depends upon the fineness of this composition, and many interesting papers have recently been presented showing the effect of this fine grinding upon the subsequent action of the cement. Microscopic examinations of the cement produced show the importance of this branch of the manufacture.

Under the old processes, where wet materials were used, and even where dry materials were pugged and wetted to put them in plastic form for moulding, much was claimed for the greater value of the cement produced from very wet composition, and this had some basis in the fact that the grinding, in olden times, was much less perfect, and many advantages were derived from the action of the water upon any soluble lime or gelatinous silica which might be free in the mixture. Very fine grinding at the present period may be said to take the place of this excess of water.

Therefore, in order to obtain the most intimate mixtures, where the powder, in its dry state, is to be placed in the revolving kiln, it is necessary that the grinding should be most thorough and the composition be an almost impalpable powder. This extremely fine grinding has been found necessary to produce the highest grades of cement, and the study of manufacturers is largely devoted to the problem of making this impalpable powder ready for the kiln at the lowest cost for power and repairs. Many forms of mills have been devised for this purpose, and will be described later, when taking up the general operation of grinding, as applied to the final preparation of the impalpable powder known as Portland cement.

Generally speaking, however, the first essential is that the rock to be ground shall be as dry as possible, in order that there may be no delays caused by choking the screens, clogging the mills, or otherwise interfering with the continuous process of

manufacture. Forms of crushers, especially adapted to care for the raw material as it comes from the dryers, have been introduced in the United States, and embrace Buchanan rolls, Smidth Kominuters, Mosser crushers, etc., all of which are described later. Important factors at this stage of the process are heavy shafting, large reserve power, large elevators, belting, etc. In some modern mills, great judgment has been shown in laying out this branch of the business, and in handling the raw material with the greatest efficiency; returning to crushers and mills all material not of the required fineness, and using every appliance to obtain the greatest efficiency at the lowest cost.

When it is considered that, in round figures, for every barrel of Portland cement, weighing 380 pounds, there is to be handled in the raw-rock process actually from 600 to 650 pounds of raw cement rock and limestone, and in the wet process actually from 1,200 to 1,500 pounds of marl and clay, it can be seen how rapidly money may be lost by improper installation at this stage of the process.

The general line of thought, in modern practice, would seem to indicate that gradual reduction is the proper process at this point of the manufacture, and that the day of the old buhr mills for grinding the dry materials is completely at an end. The forms of machinery now used are either mills like the Griffin, Huntingdon or Kent, which are iron mills of the centrifugal type, having a ball or balls operating upon the raw material, or any of the forms of tube or ball mills, where the grinding is done by the attrition of Iceland pebbles or steel balls upon the material to be treated. The distinction between mills of these two classes is that the latter will take care of stone of almost any size that can be introduced through the feed hopper, while in gyratory centrifugal mills a system of gradual reduction by passing the material through Mosser crushers and through Buchanan rolls, is necessary for the greatest efficiency. It is even now a grave question whether this efficiency would not be further increased by additional rolls, so as to reduce the material to still greater fineness before its entrance into the grinding apparatus.

Kilns.—The first kilns, as already stated, were the old bottle or dome kilns of varying sizes, and intermittent in action. The raw materials, either dry or wet, and in the shape of bricks or blocks, are placed in the kilns through doors at various heights, and covered alternately with layers of coal and coke. When the kiln is charged to a point fairly well up in the stack with these alternate layers of coal and coke, it is lighted at the bottom and allowed to burn out. In this operation, the fuel

and carbonic acid are burned out, the material shrinks, sinks to the lower part of the kiln, and the bricks run together. After the material is thoroughly cool, the mass is broken down, the under-burned yellow, and the over-burned glazed, materials are thrown out, and the clinker, in the shape of large lumps, is carried to the crusher for final grinding.

In the Dietzsch, Shoefer and Hauenschild kilns, the bricks are carried through the drying chambers to the top of the kiln, and are fed from time to time in regular charges. A sufficient quantity of coal is fed at the same time, and the operation is continuous. The burning takes place in the fire-chambers in the center of the kiln, the flame from which dries the material in the upper part of the kiln, while the material, having passed the combustion zone, goes down to the lower shaft of the kiln and is drawn therefrom at regular intervals.

In this process, as in the dome kiln, the selection of the clinker is an important factor, the over-burned and under-burned portions requiring to be removed.

Both these forms of kilns require much labor for the making of bricks before placing them in the fire. The bricks of composition must be quite dry before they are placed in dome kilns, and considerable work is required in obtaining this result, as well as in charging and drawing the kiln. Furthermore, coke, which is now becoming an expensive fuel, is required for the successful operation of dome kilns.

With kilns of the second style, a cheaper form of fuel may be used, coal of ordinary character being sufficient, but the labor item is a large one, many men being required to keep the kilns in continuous operation day and night. The old style of dome kilns, which were in general use in Europe some fifteen years ago, and were also the only kilns in operation in the United States, may be said to be gradually sinking out of commercial existence. The continuous kiln, however, is doing good work, and it is used extensively in Europe and in several works in the United States.

The cement made in these two forms of kilns differs considerably in its character from that made by the rotary-kiln process, and, where the specifications are those of moderate tensile strains at seven and twenty-eight days, has qualities which enable it to be used very successfully as they are produced without the addition of sulphate of lime, or plaster, which is essential to cement as now made in the rotary-kiln process.

During the period when the old forms of kilns were being used, various inventions were made for the introduction of the composition into the kilns without all the intermediate pro-

cesses of settling tanks, brickmaking, drying and rehandling. Among these inventions were those of DeSmedt, Lesley and Willcox, for theintroduction of hydro-carbons, as pitch, tar, petroleum waste or other similar substances, into the cement paste. The object of these inventions was to burn the raw material in a pasty condition, without falling apart, as was the case with compositions treated with water alone. Methods for the preparation of pastes of this kind under heavy pressures, in order that the bricks or blocks should be hard enough to bear the weight of the superincumbent material in the kiln, were also made at or about the same time, and while the process was used successfully for several years, the advance in the price of pitch, due to the introduction of water gas in the large gas-works, doing away with the waste coal-tar, practically made the hydro-carbons so costly that the process had to be abandoned.

The Rotary Kiln.—The growth and development of the cement industry in the United States within the past ten years are essentially due to the introduction of the rotary kiln. This kiln, invented by Ransome in England some twenty years ago and improved by Stokes, consists of an iron cylinder lined with fire-brick. The diameter increases from 60 inches at the chimney end to 66 inches at the discharge end. The kiln is about 60 feet in length, supported by trunnions at two points and trained by a pair of gears. This kiln uses as a fuel either natural gas, oil or powdered coal, which is introduced at the discharge end. When originally introduced in England, it was operated by fuel gas or by oil. Inventions were also made in the same line in the United States by Matte and Navarro. The first of these inventors, however, confined his kiln and its operation to the use of crushed stone, not pulverized, and his processes were not successful. The latter's inventions were adapted to various improvements in the revolving kiln of Ransome and Matte.

In the early days of the rotary kiln, oil was always used as fuel, though the practice of using pulverized coal in kilns of similar construction, for calcining cement as well as other materials, had been thoroughly described in various patents in the United States and elsewhere, and was well known.

During this period, the development of rotary-kiln cement was very slow, because no methods had been discovered by which the extremely quick-setting qualities of the cement could be overcome and a safe material produced. If the composition were kept low enough in lime to insure safety, the cement was too quick-setting for use, and if the lime were run up to a point high enough to make it even moderately slow setting, an imperfect cement would be produced and disintegration of the ma-

terial in briquettes and in work would sometimes ensue after a longer or shorter time. About this time, discoveries were made, based upon experiment in Germany, for seasoning cement, whereby the setting qualities of rotary-kiln cement were regulated by the use of gypsum (sulphate of lime, either raw or calcined). With this discovery, which made rotary-kiln cement a commercial product, the development of the rotary kiln began, and has continued to the present time.

The use of powdered coal was due to the advance in the price of oil. Lima oils were sold at nominal prices, and oil was used successfully in the East, as it now is on the Pacific Coast, in burning cement in rotary kilns. Natural gas is used in Kansas.

Generally stated, material prepared in the wet way, is fed into the upper end of the kiln from tanks. The kiln revolves at the rate of from a half to one revolution per minute, and is inclined from the stack, where the material is fed in, to the discharge end. The mix gradually works its way down to a point near the discharge end. At this point, which varies according to the materials used and the length of the kiln, in what is called the fire zone, the calcining of the material takes place. The material at the upper end of the kiln gives up its carbonic acid gas and moisture under the flame directed upon it from the lower end.

This lower end of the kiln projects into a stationary or movable hood, which forms a shield to protect the burner and regulate the admission of air. In this hood are nozzles which supply the requisite fuel. The mechanism for feeding the powdered coal varies in different mills. In practically every case, however, there are nozzles, through which the pulverized fuel is driven by blast, at either high or low pressure, regulated by the burner. The stream of powdered coal from the nozzle carries with it a certain quantity of air, from around the hood or from other openings, and this supports combustion. As the pulverized fuel strikes the heated kiln and is transformed into gas, a series of explosions takes place. The flame goes through the kiln, drives out the carbonic acid gas and moisture from the material at the far end, and burns the material in the fire zone to incipient vitrification. After calcination the material goes to the discharge end, where it falls into elevators or conveyors, by which it is carried to cooling towers, which are large iron cylinders subjected to forced draft, and in which the material as it falls is fully exposed to the cool air.

In the case of dry material, the composition is fed from hoppers above the upper end of the kiln, and enters the latter in the form of impalpable powder. This powder is subjected to

the flame, precisely as in the case of the wet materials, and the calcination takes place almost under the same circumstances, the fire zone varying in its extent according to the material under calcination.

During late years many improvements have been suggested for the form and length of kilns, and in the pressures to be used in calcining. Methods have also been suggested, and in many cases put in practice, notably by Professor Carpenter, of Cornell University, for the utilization of the waste heat for driving off larger percentages of moisture from wet materials, and also for steam-generating purposes.

In the first case, an auxiliary kiln of the same length as the calcining kiln has been introduced, and the flames, after traversing the first 60-foot kiln, are conducted into the second one, where they are utilized for evaporating the water from the wet mass of clay and marl composition.

In the second case, the waste heat is taken under boilers, where it is used to make steam for running the machinery of the works.

Much has also been done in relation to the size and proportions of the kilns. Originally, lengths of 40 feet were quite common. This was followed by making the kilns about 60 feet long, with a diameter of 60 inches at the chimney end and 66 inches at the discharge end. The form has been adopted very generally, and is in use in most mills.

Within the past three years, however, considerable development has taken place in the lengthening of the kilns. The first experimenter in this direction was Thomas A. Edison, who, in his works, installed kilns 150 feet long; but these, owing to difficulty in turning them and the large number of mechanical appliances connected therewith, have not yet proven absolute commercial successes. Between this size, however, and the 60 foot kiln in common use, there was a large margin in which manufacturers could experiment, and several plants have kilns from 80 up to 107 feet in length. The latter size has been adopted recently by one of the largest plants in the United States. In general practice, the 60 foot kiln is stated to give about 200 barrels per day, and those who have experimented with longer kilns claim to have reached as many as 300 barrels per day with the 80 foot length, and from 400 to 500 barrels per day with the 107 foot kilns. Should these experiments prove successful, the capacity of American Portland cement works is susceptible of very large increase at small expense. The present coal consumption in the 60 foot kilns varies from 90 to 120 pounds per barrel, where dry material is used and considerably more with wet material.

In connection with the development of the rotary kiln, many experiments have been conducted to determine the amount of heat used in the kiln and that going up the stack or otherwise wasted. Professor Richards, of Lehigh University, in a paper before the Association of Portland Cement Manufacturers, claimed that as much as 72 per cent. of the total heat supplied was lost; and, from this, various investigations as to the theoretical coal consumption in kilns have been made, leading to the methods for utilizing this waste heat in various ways. Examinations have also been made regarding the action of the heat in the kiln upon the composition contained therein, and the possible saving of the by-products contained in this material. Papers on this subject, by Professor Meade, of Easton, Pa., and by Clifford Richardson, Assoc. Am. Soc. C. E., of New York City, indicate that various percentages of sulphuric acid, potash and soda are carried out in the fuel gases and deposited at the base of the chimney. The utilization of these by-products is a subject for the manufacturer to consider, but he must also bear in mind the loss he might entail upon himself by retarding the discharge of the gases and the consequent rapidity of the calcination of the cement.

Grinding.—In the past ten years there have been many improvements in this branch of the manufacture, and in describing grinding, as a general subject in this paper, it is intended that much that is written shall apply, not only to grinding the finished materials, but also to the preparation of the raw materials, as already indicated, for the reason that most of the machinery used in the finishing process is also used in the preparatory process of manufacture.

Of course, the first thing to do with the clinker as it comes from the kilns it to cool it sufficiently for proper grinding, as it changes greatly in its characteristics and toughness, according to the time it has been exposed to air after calcination. At this stage of the process there come before the manufacturer again two methods of handling the product, and, according to which of the two he adopts, the question of crushing or not crushing will present itself. If he decides to use the ball and tube mills in batteries, he can feed the clinker immediately into the ball mill, but if, on the other hand, he uses any of the forms of gyratory centrifugal mills, such as the Griffin or Huntingdon, it will become necessary to prepare his material by gradual reduction to a proper size for the best operation of the mill to be used. These forms of crushers are various; the Mosser crusher, or coffee-mill crusher, is simply a cone revolving in a corrugated pan, and requires considerable power.

Other forms of crushers are the Buchanan corrugated rolls,

which have large capacity, and crush by direct pressure. The surface speed is about 1,000 feet per minute, and on the two rolls there is a wearing surface of about 40 square feet of the best steel, which is subject to a compressive strain only, and does no grinding. It is a slow-speed machine, and requires few repairs. Modern processes suggest that rolls of this kind be used for a form of gradual reduction, to prepare the material for Griffin, Huntingdon or Kent mills, or other mills of that general type. Such rolls should be placed one following the other, so that the material can be reduced to, say, about 12 mesh for Griffin mills; and if they are used as adjuncts to tube mills the material can be reduced to about 20 mesh, thus increasing the efficiency and capacity of the mill, providing great reduction of power and lessening the cost of labor.

In the various modifications in processes and apparatus which have been made during the past ten years, in connection with the manufacture of cement, all with the common object of attaining greater economy in cost of production, it is doubtful if in any part of the process the innovations have been more interesting and radical than those pertaining to grinding the materials and separating the finished product. Nor can there be any question that in this department the most surprising successes in the attainment of further economy have been secured. The importance of this is manifest when it is considered what a material part the cost of grinding has been. The importance of this portion of the expenditure in manufacturing is due to the fact that grinding is incident almost to the initial operation of reducing the limestone, rock and coal, and also to the final operation of pulverizing clinker to finished cement, and, from this standpoint, has made the cost account ever noticeable to the manufacturer.

At the time of the Chicago World's Fair the cement industry realized the great cost and many disadvantages incident to attrition grinding, which up to that period had been used for reducing the raw material and making the finished cement. Almost every mill ground the cement and raw material by rubbing between the upper and nether stones of a buhr mill, and bolted the resultant product in revolving reels. The horse power necessary to drive the buhr mills with the requisite friction for reducing Portland cement, the wear and tear cost and consequent labor cost of frequent recutting of the buhr stones, together with the heavy cost of reel bolting, was so large that the industry at that time was seeking to break away from this handicap.

Prior to this time, in the early nineties, some headway had been made in overcoming the cost of millstones, the first Griffin

mill, of the self-screening, suspended-roller type, having been placed in the works of the American Cement Company, at Egypt, Pa., in May, 1889. This mill is still running on natural and Portland cement clinker.

This mill utilizes in its construction the principle of a roll running against a ring or die. Heretofore, in all mills on this principle, the roll has been propelled by being pushed around by drivers, or carried on journals within the roll, and the friction and destruction of the pushing devices and journals have been great, and have involved both loss of power and excessive wear and tear.

In the Griffin mill this difficulty is overcome by a new mechanical movement which has not been used heretofore in a machine of any kind. This invention obviates the use of multiple shafts and journals in pulverizing chambers with revolving rolls, thus greatly reducing the wear and tear, and at the same time giving a greater product in proportion to the power consumed. This movement is somewhat like that of a tee-totum and is that of a revolving pendulum having a heavy steel ball which strikes the inner side of a steel ring. The grinding is done partly by the blow of the pendulum and partly by its rubbing against the ring during its peculiar motion. The mill is supplied with screens above the grinding ring, and carries scrapers which throw the material from the bottom up to the higher or grinding zone. The material is thrown out through screens as it is ground.

In practical use it secured a material reduction in the horse power cost and in the labor account. Owing to its high speed and great power, and grinding efficiency, there is a considerable wear and tear account, and where the mills are not well erected or handled, occasional break-downs occur. The introduction of mills of this type, which represent also the Huntingdon type, provided a most efficient substitute for the slow-going buhr mill at the time of the introduction of this form of grinding apparatus.

The suspended-roller type of mills represented high-speed machinery and great improvements upon the old millstones. and mills of this type are used extensively in the United States and also in many parts of Europe, there being at present nearly 800 of this type in operation in the United States alone.

The difficulties, as stated previously, caused manufacturers to look for mills of other forms, which it was hoped would prove more reliable, and entail less wear and tear. From the rapidly running Griffin or Huntingdon mill to the slow-rolling ball or tube mill was a long step, but, about 1894, ball and tube mills were adopted as substitutes for other forms of grinding machinery.

The ball mill was adopted as a breaker, for feeding to the tube mill as a finisher. The tube mill, as already stated, was first introduced in the United States in 1894. As is well known, these principles are availed of in ball and tube mills, by introducing into a revolving barrel or drum the material to be reduced with balls or with pebbles. The mass rolls continually on itself down one side of the interior of the barrel, the resulting impact and attrition sufficing to crush and wear down the material until the desired fineness is obtained.

The very simplicity of the principle of reduction by ball and tube mills was a sufficient guaranty of its reliability, and the fact that all wear, incident to attrition between the balls and pebbles and the cement, was carried on into the product, helped to offset the wear and renewal account.

The ball mill is a primary apparatus in this form of grinding, and was introduced in 1895, but it is a relatively expensive machine to maintain. Its main faults are that the normal content of steel balls will grind more than the possible screen area will pass; the balls strike upon perforations intended for the exit of materials, and gradually close the holes, and the lining consists of very large plates, which are difficult to handle and costly to make and place. On the other hand, it is claimed that it requires low horse-power in proportion to the output, little attention, and, inasmuch as the materials passed through it are screened to a given size, it is a satisfactory preliminary grinder for materials destined to be pulverized in the tube mill.

In the last two years there has appeared in the market a coarse grinder called a Kominuter, in which it has been sought to avoid the well-known faults of the ball mill. This machine consists of a drum, of about the length of its diameter, suspened in bearings by a shaft through the heads. The entire drum is surrounded by a coarse screen, or perforated plate, and outside of this is the screen frame upon which is attached the necessary wire cloth, giving an enormous screening surface. The drum is lined with wrought iron grinding plates, arranged in steps similar to the ball mill. The material enters beside the shaft, travels the full length of the drum, and finds exit through ports arranged at the outlet end. The particles which are larger than the openings in the inside screen, or perforated plate, are returned automatically to the center of the mill by buckets and "S" shaped pipes. The materials passing the inside screen are caught on the outside screen, and the rejections are returned to the mill in the same manner.

The tube mill operates upon the same general principles as the ball mill, and is intended to be a finishing apparatus in this form of grinding. There are several tube and ball mills which

vary but slightly in mechanical details and efficiency, and, for practical purposes, it may be stated that the tube mill is about the same to-day as when first brought into the Portland cement industry in the United States.

The Kominuter is intended to be used as a preliminary grinder for ball mills and in the ball and tube mill combination, and it is sought to make use of each machine in the field of its greatest economy, the object being that each mill will have its own work in this slow-moving field of gradual reduction.

The ball mills were introduced in Germany about ten years ago, and the general design since then has not been altered materially. The various forms of these mills are made by the Kruppes Grusenwerk, F. L. Smidth & Company, and the Allis-Chalmers Company in the United States. Batteries of ball and tube mills are operated together. They take the clinker as it comes from the kilns, and grind it into the impalpable powder known as Portland cement.

In addition to the mills already described, a new mill has recently come into use, and is known as the Kent mill, or revolving ring mill, having three grinding rolls which are mounted on horizontal shafts, and press directly against the surface of the heavy vertical ring, on the center surface of which the cement is fed and between which and the rolls it is pulverized. This is a slow-running mill. The ring is revolved at sufficient speed to utilize the centrifugal force to hold the cement on its inner surface, thus avoiding the use of scrapers for bringing the material into position to be crushed.

The rolls simply roll over the cement under great pressure, and crush it to impalpable powder, without measurable friction, the action being claimed to be purely a crushing one, distinguished from that of the ball mill or buhr stone.

Coal Grinding.—In addition to the raw materials and the clinker which require the use of the various forms of grinding machinery described, there is also another important use for this machinery in modern mills using coal in the rotary-kiln process, and the foregoing description of the machinery applies fully to that use—the preparation of the pulverized coal for use in the kilns. This is usually done in a separate building, where the coal, after drying in any of the forms of dryers described, is run through mills, generally of the gyratory character, and reduced to impalpable powder, in which form it is introduced into the kiln. This grinding is usually done in a building separated from the rest of the plant, in order to avoid any danger from explosion or fire. The modern construction of these buildings provides for ample ventilation and large head-room, thus lessening the possibility of the explosion of finely pulverized fuel.

Storehouses.—After the material comes from the grinding machine it is carried by elevators into conveyors, and by the latter distributed through the stockhouses. These buildings, in mills of large capacity, are immense edifices of concrete or stone, providing storage room for hundreds of thousands of barrels. The pulverized material is generally run into bins, ranging in capacity from 2,000 to 5,000 barrels, thus providing units of various sizes for testing purposes. Plans have been made for storehouses in which the cement is to be run into hopper-shaped bins, thus enabling the material to be run directly from the hoppers into barrels or bags, avoiding much of the present cost of loading, in plants where the cement is run directly to the floors of one-story warehouses.

Many methods of loading, by machines of various characters—packing cement in barrels or bags—are in use, but have not been adopted generally. One of the most important improvements in stockhouse management has been the introduction of bag-cleaning machinery, both at the mills and in the large cities, by which bags are gathered in the cement-consuming markets and are shaken and cleaned and the loose cement saved, thus effecting a great economy in freight by returning the bags to the mill in their clean condition. Similar practice at the mills saves a considerable quantity of cement, which, otherwise would be wasted, and also insures a better repair of the bags and a better appearance of the packages.

TESTING OF CEMENT.

The methods of testing cement which have been considered standard by American engineers are those adopted by the American Society of Civil Engineers in 1885, being recommended by a strong committee with full theoretical and practical knowledge of the subject. Lately it has been felt that this report was not quite up to the advances which have been made in the manufacture of Portland cement, and another equally strong committee has been appointed to consider the subject. This committee brought in a progress report in January, 1903, and made some modifications of the report in January, 1904. At the same time it reported that some points had not yet been settled and therefore asked for a continuance.

The American Society for Testing Materials has also had a strong committee at work upon the subject, and this committee has made a report which has been officially adopted by the Society. It embodies much of the matter and phraseology of the report to the American Society of Civil Engineers, and is given in full as the only official statement of standard practice. The methods of examination recommended are given in this chapter and the specifications will be found in the following chapter. Following this official document will be found a statement of such matters in the report to the American Society of Civil Engineers as were omitted from this document.

METHODS OF THE AMERICAN SOCIETY FOR TESTING MATERIALS.

General Observations.—1. These remarks have been prepared with a view of pointing out the pertinent features of the various requirements and the precautions to be observed in the interpretation of the results of the tests.

2. The Committee would suggest that the acceptance or rejection under these specifications be based on tests made by an experienced person having the proper means for making the tests.

Specific Gravity.—3. Specific gravity is useful in detecting adulteration or underburning. The results of tests of specific gravity are not necessarily conclusive as an indication of the quality of a cement, but when in combination with the results of other tests may afford valuable indications.

Fineness.—4. The sieves should be kept thoroughly dry.

Time of Setting.—5. Great care should be exercised to maintain the test pieces under as uniform conditions as possible. A sudden change or wide range of temperature in the room in which tests are made, a very dry or humid atmosphere, and other irregularities vitally affect the rate of setting.

Tensile Strength.—6. Each consumer must fix the minimum requirements for tensile strength to suit his own conditions. They shall, however, be within the limits stated.

Constancy of Volume.—7. The tests for constancy of volume are divided into two classes, the first normal, the second accelerated. The latter should be regarded as a precautionary test only, and not infallible. So many conditions enter into the making and interpreting of it that it should be used with extreme care.

8. In making the pats the greatest care should be exercised to avoid initial strains due to molding or to too rapid drying out during the first twenty-four hours. The pats should be preserved under the most uniform conditions possible, and rapid changes of temperature should be avoided.

9. The failure to meet the requirements of the accelerated tests need not be sufficient cause for rejection. The cement may, however, be held for twenty-eight days, and a retest made at the end of that period. Failure to meet the requirements at this time should be considered sufficient cause for rejection, although in the present state of our knowledge it can not be said that such failure necessarily indicates unsoundness, nor can the cement be considered entirely satisfactory because it passes the tests.

Selection of Sample.—1. The sample shall be a fair average of the contents of the package. It is recommended, that where conditions permit, one barrel in every ten be sampled.

2. All samples should be passed through a sieve having twenty meshes per linear inch, in order to break up lumps and remove foreign material; this is also a very effective method for mixing them together in order to obtain an average. For determining the characteristics of a shipment of cement, the individual samples may be mixed and the average tested; where time will permit, however, it is recommended that they be tested separately.

Method of Sampling.—3. Cement in barrels should be sampled through a hole made in the center of one of the staves, midway between the heads, or in the head, by means of an auger or a sampling iron similar to that used by sugar inspectors. If in bags, it should be taken from surface to center.

Chemical Analysis.—4. Method—As a method to be followed

for the analysis of cement, that proposed by the Committee on Uniformity in the Analysis of Materials for the Portland Cement Industry, of the New York Section of the Society for Chemical Industry, and given herein on a subsequent page, is recommended.

Specific Gravity.—5. Apparatus and Method—The determination of specific gravity is most conveniently made with Le Chatelier's apparatus. This consists of a flask of 120 cu. cm. (7.32 cu. ins.) capacity, the neck of which is about 20 cm. (7.87 ins.) long; in the middle of this neck is a bulb, above and below which are two marks; the volume between these two marks is 20 cu. cm. (1.22 cu. ins.). The neck has a diameter of about 9 mm. (0.35 in.), and is graduated into tenths of cubic centimeters above the upper mark.

6. Benzine (62 degrees Baume naphtha), or kerosene free from water, should be used in making the determination.

7. The specific gravity can be determined in two ways:

(1) The flask is filled with either of these liquids to the lower mark,, and 64 gr. (2.25 oz.) of powder, previously dried at 100 degrees C. (212 degrees F.) and cooled to the temperature of the liquid, is gradually introduced through a funnel (the stem of which extends into the flask to the top of the bulb), until the upper mark is reached. The difference in weight between the cement remaining and the original quantity (64 gr.) is the weight which has displaced 20 cu. cm.

8. (2) The whole quantity of the powder is introduced, and the level of the liquid rises to some division of the graduated neck. This reading plus 20 cu. cm. is the volume displaced by 64 gr. of the powder.

9. The specific gravity is then obtained from the formula:

$$\text{Specific Gravity} = \frac{\text{Weight of Cement}}{\text{Displaced Volume}}$$

10. The flask, during the operation, is kept immersed in water in a jar, in order to avoid variations in the temperature of the liquid. The results should agree within 0.01.

11. A convenient method for cleaning the apparatus is as follows: The flask is inverted over a large vessel, preferably a glass jar, and shaken vertically until the liquid starts to flow freely; it is then held still in a vertical position until empty; the remaining traces of cement can be removed in a similar manner by pouring into the flask a small quantity of clean liquid and repeating the operation.

Fineness.—12. Apparatus—The sieve should be circular, about 20 cm. (7.87) ins.) in diameter, 6 cm. (2.36 ins.) high, and provided with a pan 5 cm. (1.97 ins.) deep, and a cover.

13. The wire cloth should be woven (not twilled) from brass wire having the following diameters:

No. 100, 0.0045 in.; No. 200, 0.0024 in.

14. This cloth should be mounted on the frames without distortion; the mesh should be regular in spacing and be within the following limits:

No. 100, 96 to 100 meshes to the linear inch.
No. 200, 188 to 200 meshes to the linear inch.

15. Fifty grams (1.76 oz.) or 100 gr. (3.52 oz.) should be used for the test, and dried at a temperature of 100 degrees C. (212 degrees F.) prior to sieving.

16. Method. The thoroughly dried and coarsely screened sample is weighed and placed on the No. 200 sieve, which, with pan and cover attached, is held in one hand in a slightly inclined position, and moved forward and backward, at the same time striking the side gently with the palm of the other hand, at the rate of about 200 strokes per minute. The operation is continued until not more than one-tenth of 1 per cent. passes through after one minute of continuous sieving. The residue is weighed, then placed on the No. 100 sieve and the operation repeated. The work may be expedited by placing in the sieve a small quantity of large shot. The results should be reported to the nearest tenth of 1 per cent.

Normal Consistency.—17. Method. This can best be determined by means of the Vicat Needle Apparatus, which consists of a frame, bearing a movable rod, with a cap at one end and at the other a cylinder, 1 cm. (0.39 in.) in diameter, the cap, rod and cylinder weighing 300 gr. (10.58 oz.). The rod, which can be held in any desired position by a screw, carries an indicator, which moves over a scale (graduated to centimeters) attached to the frame. The paste is held by a conical, hard-rubber ring, 7 cm. (2.76 ins.) in diameter at the base and 4 cm. (1.57 ins.) high, resting on a glass plate about 10 cm. (3.94 ins.) square.

18. In making the determination, the same quantity of cement as will be subsequently used for each batch in making the briquettes (but not less than 500 grams) is kneaded into a paste, as described in paragraph 39, and quickly formed into a ball with the hands, completing the operation by tossing it six times from one hand to the other, maintained 6 ins. apart; the ball is then pressed into the rubber ring, through the larger opening, smoothed off, and placed (on its large end) on a glass plate and the smaller end smoothed off with a trowel; the paste, confined in the ring, resting on the plate, is placed under the rod bearing the cylinder, which is brought in contact with the surface and quickly released.

19. The paste is of normal consistency when the cylinder penetrates to a point in the mass 10 mm. (0.39 in.) below the top of the ring. Great care must be taken to fill the ring exactly to the top.

20. The trial pastes are made with varying percentages of water until the correct consistency is obtained.

NOTE.—*The Committee on Standard Specifications inserts the following table for temporary use, to be replaced by one to be devised by the Committee of the American Society of Civil Engineers.*

PERCENTAGE OF WATER FOR STANDARD MIXTURES.

Neat	1-1	1-2	1-3	1-4	1-5	Neat	1-1	1-2	1-3	1-4	1-5
18	12.0	10.0	9-0	8.4	8.0	33	17.0	13.3	11.5	10.4	9.6
19	12.3	10.2	9.2	8.5	8.1	34	17.3	13.6	11.7	10.5	9.7
20	12 7	10.4	9.3	8.7	8.2	35	17.7	13.8	11.8	10.7	9.9
21	13.0	10.7	9.5	8.8	8.3	36	18.0	14.0	12.0	10.8	10 0
22	13.3	10.9	9.7	8.9	8.4	37	18.3	14 2	12.2	10.9	10.1
23	13.7	11.1	9.8	9.1	8.5	38	18.7	14.4	12.3	11.1	10.2
24	14.0	11.3	10.0	9.2	8.6	39	19.0	14.7	12.5	11.2	10.3
25	14.3	11.6	10.2	9.3	8.8	40	19.3	14.9	12.7	11.3	10.4
26	14.7	11.8	10.3	9.5	8 9	41	19.7	15.1	12.8	11.5	10.5
27	15.0	12.0	10.5	9 6	9.0	42	20.0	15.3	13.0	11.6	10.6
28	15.3	12.2	10.7	9.7	9.1	43	20.3	15.6	13.2	11.7	10.7
29	15.7	12.5	10.8	9.9	9.2	44	20.7	15.8	13 3	11.9	10.8
30	16.0	12.7	11.0	10.0	9 3	45	21.0	16.0	13.5	12.0	11.0
31	16.3	12 9	11.2	10.1	9.4	46	21.3	16.1	13.7	12.1	11.1
32	16.7	13.1	11.3	10.3	9.5						

	1 to 1	1 to 2	1 to 3	1 to 4	1 to 5
Cement	500	333	250	200	167
Sand	500	666	750	800	833

Time of Setting.—21. Method. For this purpose the Vicat Needle, which has already been described in paragraph 17, should be used.

22. In making a test, a paste of normal consistency is molded and placed under the rod, as described in paragraph 18; this rod, bearing a cap at one end and a needle, 1 mm. (0.039 in.) in diameter, at the other, weighing 300 gr. (10.58 oz.). The needle is then carefully brought in contact with the surface of the paste and quickly released.

23. The setting is said to have commenced when the needle ceases to pass a point 5 mm. (0.20 in.) above the upper surface of the glass plate, and is said to have terminated the moment the needle does not sink visibly into the mass.

24. The test pieces should be stored in moist air during the

test; this is accomplished by placing them on a rack over water contained in a pan and covered with a damp cloth, the cloth to be kept away from them by means of a wire screen; or they may be stored in a moist box or closet.

25. Care should be taken to keep the needle clean, as the collection of cement on the sides of the needle retards the penetration, while cement on the point reduces the area and tends to increases the penetration.

26. The determination of time of setting is only approximate, being materially affected by the temperature of the mixing water, the temperature and humidity of the air during the test, the percentage of water used, and the amount of molding the paste receives.

Standard Sand.—27. For the present the Committee recommends the natural sand from Ottawa, Ill., screened to pass a sieve having 20 meshes per linear inch and retained on a sieve having 30 meshes per linear inch; the wires to have diameters of 0.0165 and 0.0112 in., respectively, *i. e.,* half the width of the opening in each case. Sand having passed the No. 20 sieve shall be considered standard when not more than 1 per cent. passes a No. 30 sieve after one minute continuous sifting of a 500-gram sample.

28. The Sandusky Portland Cement Company, of Sandusky, Ohio, has agreed to undertake the preparation of this sand and to furnish it at a price only sufficient to cover the actual cost of preparation.

Form of Briquette.—29. While the form of the briquette recommended by a former committee of the Society is not wholly satisfactory, this Committee is not prepared to suggest any change, other than rounding off the corners by curves of one-half inch radius.

Molds.—30. The molds should be made of brass, bronze or some equally non-corrodible material, having sufficient metal in the sides to prevent spreading during molding.

31. Gang molds, which permit molding a number of briquettes at one time, are preferred by many to single molds; since the greater quantity of mortar that can be mixed tends to produce a greater uniformity in the results.

32. The molds should be wiped with an oily cloth before using.

Mixing.—33. All proportions should be stated by weight; the quantity of water to be used should be stated as a percentage of the dry material.

34. The metric system is recommended because of the convenient relation of the gram and the cubic centimeter.

35. The temperature of the room and the mixing water

should be as near 21 degrees C. (70 degrees F.) as it is practicable to maintain it.

36. The sand and cement should be thoroughly mixed dry. The mixing should be done on some non-absorbing surface, preferably plate glass. If the mixing must be done on an absorbent surface it should be thoroughly dampened prior to use.

37. The quantity of material to be mixed at one time depends on the number of test pieces to be made; about 1,000 gr. (35.28 oz.) makes a convenient quantity to mix, especially by hand methods.

38. Method. The material is weighed and placed on the mixing table, and a crater formed in the center, into which the proper percentage of clean water is poured; the material on the outer edge is turned into the crater by the aid of a trowel. As soon as the water has been absorbed, which should not require more than one minute, the operation is completed by vigorously kneading with the hands for an additional 1½ minutes, the process being similar to that used in kneading dough. A sand-glass affords a convenient guide for the time of kneading. During the operation of mixing, the hands should be protected by gloves, preferably of rubber.

Molding.—39. Having worked the paste or mortar to the proper consistency, it is at once placed in the molds by hand.

40. Method. The molds should be filled at once, the material pressed in firmly with the fingers and smoothed off with a trowel without ramming; the material should be heaped up on the upper surface of the mold, and, in smoothing off, the trowel should be drawn over the mold in such a manner as to exert a moderate pressure on the excess material. The mold should be turned over and the operation repeated.

41. A check upon the uniformity of the mixing and molding is afforded by weighing the briquettes just prior to immersion, or upon removal from the moist closet. Briquettes which vary in weight more than 3 per cent. from the average should not be tested.

Storage of the Test Pieces.—42. During the first 24 hours after molding, the test pieces should be kept in moist air to prevent them from drying out.

43. A moist closet or chamber is so easily devised that the use of the damp cloth should be abandoned if possible. Covering the test pieces with a damp cloth is objectionable, as commonly used, because the cloth may dry out unequally, and in consequence the test pieces are not all maintained under the same condition. Where a moist closet is not available, a cloth may be used and kept uniformly wet by immersing the ends in water. It should be kept from direct contact with the test

pieces by means of a wire screen or some similar arrangement.

44. A moist closet consists of a soapstone or slate box, or a metal-lined wooden box—the metal lining being covered with felt and this felt kept wet. The bottom of the box is so constructed as to hold water, and the sides are provided with cleats for holding glass shelves on which to place the briquettes. Care should be taken to keep the air in the closet uniformly moist.

45. After 24 hours in moist air, the test pieces for longer periods of time should be immersed in water maintained as near 21 degrees C. (70 degrees F.) as practicable; they may be stored in tanks or pans, which should be of non-corrodible material.

Tensile Strength.—46. The test may be made on any standard machine. A solid metal clip is recommended. This clip is to be used without cushioning at the points of contact with the test specimen. The bearing at each point of contact should be a quarter of an inch wide, and the distance between the centers of contact on the same clip should be one and a quarter inches.

17. Test pieces should be broken as soon as they are removed from the water. Care should be observed in centering the briquettes in the testing machine, as cross-strains, produced by improper centering, tend to lower the breaking strength. The load should not be applied too suddenly, as it may produce vibration, the shock from which often breaks the briquette before the ultimate strength is reached. Care must be taken that the clips and the sides of the briquettte be clean and free from grains of sand or dirt which would prevent a good bearing. The load should be applied at the rate of 600 pounds per minute. The average of the briquettes of each sample tested should be taken as the test, excluding any results which are manifestly faulty.

Constancy of Volume.—48. Methods. Tests for constancy of volume are divided into two classes: (1) normal tests, or those made in either air or water maintained at about 21 degrees C. (70 degrees F.), and (2) accelerated tests, or those made in air, steam or water at a temperature of 45 degrees C. (115 degrees F.) and upward. The test pieces should be allowed to remain 24 hours in moist air before immersion in water or steam, or preservation in air.

49. For these tests, pats about 7½ cm. (2.95 ins.) in diameter, 1½ cm. (0.49 in.) thick at the center, and tapering to a thin edge, should be made, upon a clean glass plate [about 10 cm. (3.94 ins.) square], from cement paste of normal consistency.

50. Normal Test. A pat is immersed in water maintained as near 21 degrees C. (70 degrees F.) as possible for 28 days, and observed at intervals. A similar pat is maintained in air at ordinary temperature and observed at intervals.

51. Accelerated Test. A pat is exposed in any convenient way in an atmosphere of steam, above boiling water, in a loosely closed vessel.

52. To pass these tests satisfactorily, the pats should remain firm and hard, and show no signs of cracking, distortion or disintegration.

53. Should the pat leave the plate, distortion may be detected best with a straight-edge applied to the surface which was in contact with the plate.

ADDITIONAL REMARKS OF THE COMMITTEE OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS.

On several matters which have been considered this Committee has not reached final conclusions, but feels that it should make a report of progress, that the Society may be informed of the results of its investigations and conclusions..

Selection of Sample.—The selection of the sample for testing is a detail that must be left to the discretion of the engineer; the number and the quantity to be taken from each package will depend largely on the importance of the work, the number of tests to be made and the facilities for making them.

Significance of Chemical Analysis.—Chemical analysis may render valuable service in the detection of adulteration of cement with considerable amounts of inert material, such as slag or ground limestone. It is of use, also, in determining whether certain constituents, believed to be harmful when in excess of a certain percentage, as magnesia and sulphuric anhydride, are present in inadmissible proportions. While not recommending a definite limit for these impurities, the Committee would suggest that the most recent and reliable evidence appears to indicate that magnesia to the amount of 5 per cent. and sulphuric anhydride to the amount of 1.75 per cent. may safely be considered harmless.

The determination of the principal constituents of cement, silica, alumina, iron oxide and lime, is not conclusive as an indication of quality. Faulty character of cement results more frequently from imperfect preparation of the raw material, or defective burning, than from incorrect proportions of the constituents. Cement made from very finely ground material and thoroughly burned, may contain much more lime than the amount usually present and still be perfectly sound. On the other hand, cements low in lime may, on acount of careless

preparation of the raw material, be of dangerous character. Further, the ash of the fuel used in burning may so greatly modify the composition of the product as largely to destroy the significance of the results of analysis.

Significance of the Specific Gravity Test.—The specific gravity of cement is lowered by underburning, adulteration and hydration, but the adulteration must be in considerable quantity to affect the results appreciably. Inasmuch as the differences in specific gravity are usually very small, great care must be exercised in making this determination.

Significance of the Fineness Test.—It is generally accepted that the coarser particles in cement are practically inert, and it is only the extremely fine powder that possesses adhesive or cementing qualities. The more finely cement is pulverized, all other conditions being the same, the more sand it will carry and produce a mortar of a given strength. The degree of final pulverization which the cement receives at the place of manufacture is ascertained by measuring the residue retained on certain sieves. Those known as the No. 100 and No. 200 sieves are recommended for this purpose.

Significance of the Normal Consistency Test.—The use of a proper percentage of water in making the pastes from which pats, tests of setting and briquettes are made, is exceedingly important, and affects vitally the results obtained. The determination consists in measuring the amount of water required to reduce the cement to a given state of plasticity, or to what is usually designated the normal consistency. Various methods have been proposed for making this determination, none of which has been found entirely satisfactory, but the Committee recommends the one given above. The trial pastes are made with varying percentages of water until the correct consistency is obtained. The Committee has recommended as normal, a paste, the consistency of which is rather wet, because it believes that variations in the amount of compression to which the briquette is subjected in molding are likely to be less with such a paste. Having determined in this manner the proper percentage of water required to produce a neat paste of normal consistency, the proper percentage required for the sand mortars is obtained from an empirical formula. The Committee hopes to devise such a formula. The subject proves to be a very difficult one, and although the Committee has given it much study, it is not yet prepared to make a definite recommendation.

Significance of Test of Time of Setting.—The object of this test is to determine the time which elapses from the moment water is added until the paste ceases to be fluid and plastic

(called the initial set), and also the time required for it to acquire a certain degree of hardness (called the final or hard set). The former of these is the more important, since, with the commencement of setting, the process of crystallization or hardening is said to begin. As a disturbance of this process may produce a loss of strength, it is desirable to complete the operation of mixing and molding or incorporating the mortar into the work before the cement begins to set. It is usual to measure arbitrarily the beginning and end of the setting by the penetration of weighted wires of given diameters.

Standard Sand.—The Committee recognizes the grave objections to the standard quartz now generally used, especially on account of its high percentage of voids, the difficulty of compacting in the molds, and its lack of uniformity; it has spent much time in investigating the various natural sands which appeared to be available and suitable for use..

Mixing and Molding Machines.—The Committee, after investigation of the various mechanical mixing machines, has decided not to recommend any machine that has thus far been devised, for the following reasons: (1) the tendency of most cement to ball up in the machine, thereby preventing the working of it into a homogeneous paste; (2) there are no means of ascertaining when the mixing is complete without stopping the machine; and (3) the difficulty of keeping the machine clean.

The Committee has been unable to secure satisfactory results with the present molding machines; the operation of machine molding is very slow, and the present types permit of molding but one briquette at a time, and are not practicable with the pastes or mortars recommended.

Significance of Test of Consistency of Volume.—The object is to develop those qualities which tend to destroy the strength and durability of a cement. As it is highly essential to determine such qualities at once, tests of this character are for the most part made in a very short time, and are known, therefore, as accelerated tests. Failure is revealed by cracking, checking, swelling or disintegration, or all of these phenomena. A cement which remains perfectly sound is said to be of constant volume.

METHODS OF CHEMICAL ANALYSIS OF THE SOCIETY FOR CHEMICAL INDUSTRY.

Method suggested for the chemical analysis of limestones, raw mixtures and Portland cements by the Committee on Uniformity in Technical Analysis, with the advice of W. F. Hillebrand.

Solution.—One-half gram of the finely powdered substance is to be weighed out and, if a limestone or unburned mixture, strongly ignited in a covered platinum crucible over a strong blast for 15 minutes, or longer if the blast is not powerful enough to effect complete conversion to a cement in this time. It is then transferred to an evaporating dish, preferably of platinum for the sake of celerity in evaporation, moistened with enough water to prevent lumping, and 5 to 10 c. c. of strong HCl added and digested, with the aid of gentle heat and agitation, until solution is completed. Solution may be aided by light pressure with the flattened end of a glass rod.* The solution is then evaporated to dryness, as far as this may be possible on the bath.

Silica.—The residue, without further heating, is treated at first with 5 to 10 c. c. of strong HCl, which is then diluted to half strength or less, or upon the residue may be poured at once a larger volume of acid of half strength. The dish is then covered and digestion allowed to go on for 10 minutes on the bath, after which the solution is filtered and the separated silica washed throughly with water. The filtrate is again evaporated to dryness, the residue, without further heating, taken up with acid and water and the small amount of silica it contains separated on another filter paper. The papers containing the residue are transferred wet to a weighed platinum crucible, dried, ignited, first over a Bunsen burner until the carbon of the filter is completely consumed, and finally over the blast for 15 minutes and checked by a further blasting for 10 minutes or to constant weight. The silica, if great accuracy is desired, is treated in the crucible with about 10 c. c. of HFl and four drops of H_2SO_4 and evaporated over a low flame to complete dryness. The small residue is finally blasted for a minute or two, cooled and weighed. The difference between this weight and the weight previously obtained gives the amount of silica.**

Alumina and Iron.—The filtrate, about 250 c. c., from the second evaporation for SiO_2, is made alkaline with NH_4OH after adding HCl, if need be, to insure a total of 10 to 15 c.c. strong acid, and boiled to expel excess of NH_3, or until there is but a faint odor of it, and the precipitated iron and aluminum hydrates, after settling, are washed once by decantation and slightly on the filter. Setting aside the filtrate, the precipitate is dissolved in hot dilute HCl, the solution passing

*If anything remains undecomposed, it should be separated, fused with a little Carbonate of Soda, dissolved and added to the original solution. Of course a small amount of non-gelatinous silica is not to be mistaken for undecomposed matter.

** For ordinary control work in the plant laboratory this correction may, perhaps, be neglected; the double evaporation, never.

into the beaker in which the precipitation was made. The aluminum and iron are then reprecipitated by NH_4OH, boiled and the second precipitate collected and washed on the same filter used in the first instance. The filter paper, with the precipitate, is then placed in a weighed platinum crucible, the paper burned off and the precipitate ignited and finally blasted 5 minutes, with care to prevent reduction, cooled and weighed as $Al_2O_3+Fe_2O_3$.*

Iron.—The combined iron and aluminum oxides are fused in a platinum crucible at a very low temperature with about 3 to 4 grams of $KHSO_4$, or, better, $NaHSO_4$, the melt taken up with so much dilute H_2SO_4 that there shall be no less than 5 grams absolute acid and enough water to effect solution on heating. The solution is then evaporated and eventually heated till acid fumes come off copiously. After cooling and redissolving in water the small amount of silica is filtered out, weighed, and corrected by HFl and H_2SO_4 ** The filtrate is reduced by zinc, or preferably by hydrogen sulphide, boiling out the excess of the latter afterwards whilst passing CO_2 through the flask, and titrated with permanganate.*** The strength of the permanganate solution should not be greater than .0040 gr. Fe_2O_3 per c. c.

Lime.—To the combined filtrate from the $Al_2O_3+Fe_2O_3$ precipitate a few drops of NH_4OH are added, and the solution brought to boiling. To the boiling solution 20 c. c. of a saturated solution of ammonium oxalate is added, and the boiling continued until the precipitated CaC_2O_4 assumes a well-defined granular form. It is then allowed to stand for 20 minutes, or until the precipitate has settled, and then filtered and washed. The precipitate and filter are placed wet in a platinum crucible, and the paper burned off over a small flame of a Bunsen burner. It is then ignited, redissolved in HCl, and the solution made up to 100 c. c. with woter. Ammonia is added in slight excess, and the liquid is boiled. If a small amount of Al_2O_3 separates this is filtered out, weighed, and the amount added to that found in the first determination, when greater accuracy is desired. The lime is then reprecipitated by ammonium oxalate, allowed to stand until settled, filtered and washed, **** weighed as oxide by ignition and

* This precipitate contains TiO_2, P_2O_5, Mn_3O_4.

** This correction of Al_2O_3, Fe_2O_2 for silica should not be made when the HFl correction of the main silica has been omitted, unless that silica was obtained by only one evaporation and filtration. After two evaporations and filtrations 1 to 2 mg of SiO_2 are still to be found with the Al_2O_3, Fe_2O_3.

*** In this way only is the influence of titanium to be avoided and a correct result obtained for iron.

**** The volume of wash water should not be too large. *Vide* Hillebrand.

blasting in a covered crucible to constant weight, or determined with dilute standard permanganate.*

Magnesia.—The combined filtrates from the calcium precipitates are acidified with HCl and concentrated on the steam bath to about 150 c. c., 10 c. c. of saturated solution of $Na(NH_4)HPO_4$ are added, and the solution boiled for several minutes. It is then removed from the flame and cooled by placing the beaker in ice water. After cooling, NH_4OH is added drop by drop with constant stirring until the crystalline ammonium-magnesium ortho-phosphate begins to form, and then in moderate excess, the stirring being continued for several minutes. It is then set aside for several hours in a cool atmosphere and filtered. The precipitate is redissolved in hot dilute HCl, the solution made up to about 100 c. c., 1 c. c. of a saturated solution of $Na(NH_4)HPO_4$ added, and ammonia drop by drop, with constant stirring until the precipitate is again formed as described and the ammonia is in moderate excess. It is then allowed to stand for about two hours when it is filtered on a paper or a Gooch crucible, ignited, cooled and weighed as $Mg_2P_2O_7$

Potash and Soda.—For the precipitation of the alkalies, the well-known method of Prof. J. Lawrence Smith is to be followed, either with or without the addition of $CaCO_3$ with NH_4Cl.

Sulphuric Anhydride.—One gram of the substance is dissolved in 15 c. c. of HCl, filtered and residue washed thoroughly.**

The solution is made up to 250 c. c. in a beaker and boiled. To the boiling solution 10 c. c. of a saturated solution of $BaCl_2$ is added slowly drop by drop from a pipette and the boiling continued until the precipitate is well formed, or digestion on the steam bath may be substituted for the boiling. It is then set aside over night, or for a few hours, filtered, ignited and weighed as BaSO

Total Sulphur.—One gram of the material is weighed out in a large platinum crucible and fused with Na_2CO_3 and a little KNO_3, being careful to avoid contamination from sulphur in the gases from source of heat. This may be done by fitting the crucible in a hole in an asbestos board. The melt is treated in the crucible with boiling water and the liquid poured into a tall narrow beaker and more hot water added until the mass is disintegrated. The solution is then filtered. The filtrate contained in a No. 4 beaker is to be acidulated with HCl and made

*The accuracy of this method admits of criticism, but its convenience and rapidity demand its insertion.

**Evaporation to dryness is unnecessary, unless gelatinous silica should have separated and should never be performed on a bath heated by gas. *Vide* Hillebrand.

up to 250 c. c. with distilled water, boiled, the sulphur precipitated as $BaSO_4$ and allowed to stand over night or for a few hours.

Loss on Ignition.—Half a gram of cement is to be weighed out in a platinum crucible, placed in a hole in an asbestos board so that about three-fifths of the crucible projects below, and blasted 15 minutes, preferably with an inclined flame. The loss by weight, which is checked by a second blasting of five minutes, is the loss on ignition.

Recent investigations have shown that large errors in results are often due to the use of impure distilled water and reagents. The analyst should, therefore, test his distilled water by evaporation and his reagents by appropriate tests before proceeding with his work.

METHODS OF TESTING OF THE CORPS OF ENGINEERS, U. S. ARMY.

The document, Professional Papers No. 28, Corps of Engineers, U. S. A., is mainly in accord with the adopted report of the American Society of Civil Engineers. It states the general object of tests in the following words:

The object of tests is to establish two probabilites: First, that the product of the given cement will develop the desired strength and hardness soon enough to enable it to bear the stresses designed for it; second, that it will never thereafter fall below that strength and hardness.

With respect to fineness it emphasizes the necessity of determining the proportion of very fine cement rather than the proportion above a certain size. It therefore recommends the No. 100 sieve for both Portland and natural cements, and frequent inspection of sieves.

A test for *specific gravity* is recommended. The reasons for it are stated as follows:

This test is made with simple appliances, and its result is immediately known. It appears to connect itself quite definitely with the degree of calcination which the cement has received. The higher the burning, short of vitrification, the better the cement and the higher the specific gravity. This test has another value, in that the adulterations of Portland cement most likely to be practiced and most to be feared are made with materials which reduce the specific gravity. The test is therefore of value in determining a properly burned, non-adulterated Portland. If underburned, the specific gravity may fall below 3; it may reach 3.5 if the cement has been overburned. No other hydraulic cement is so heavy in proportion to volume, natural cement having a specific gravity

of about 2.5 to 2.8 and puzzolan (slag) of about 2.7 to 2.8. Properly burned Portland, adulterated with slag, will fall below 3.1.

With reference to the test of activity or *time of setting* some of the statements are somewhat at variance with those of prominent manufacturers, and all engineers will not be in strict accord with them all. They are as follows:

This test is direct in so far as its limits relate to the time necessary to get the cement in place after mixing, which must not be greater than the time of initial set, and to the time within which the cement product must take its load, which must not be less than the time of permanent set. It is indirect in so far as its limits relate to the probable final strength, elasticity, and hardness of the cement mixtures. In the latter respect it appears to be reasonably well established that cements exhibiting great activity give, after long periods, results inferior to those with action less rapid. Generally speaking, both periods of set are lengthened by increase of moisture and shortened by increase of temperature. Some manufacturers claim that their cements show their best results when gauged with particular percentages of water. It is not considered good policy to encourage these peculiarities at the expense of the uniformity of tests which is so greatly desired. It is better to adopt a definite proportion of water for gauging and require all cements of the same class to stand or fall on their showing when so gauged. Such a percentage, adopted and known, will probably be used by manufacturers in testing goods sold to the Engineer Department, and a greater harmony between mill and field tests of the same cement will result. In gauging Portland cement in damp weather the samples should be thoroughly dried before adding water. This precaution is not deemed necessary with natural cement. Sufficient uniformity of temperature will result if the testing room be comfortably warmed in winter and the specimens be kept out of the sun in a cool room in summer, and under a damp cloth till set.

Regarding tests of strength the board considers the 7 and 28-day tests for *tensile strength* the best on the whole. With regard to variation in results it says that if the conditions have been carefully observed and several discrepant results are obtained, the highest may be right, but the others are certainly wrong, and that no averaging should be done. The board classes quick setting with early attainment of high tensile strength and considers that the relation between

early hydraulic intensity and the final excellence of a cement product are equally applicable to the indications from tensile tests. This will hardly be accepted by manufacturers as true for every cement under all conditions, though nearly all will agree with the board that

A cement which tests moderately high at 7 days and shows a substantial increase to 28 days is more likely to reach the maximum strength slowly and retain it indefinitely with a low modulus of elasticity than a cement which tests abnormally high at 7 days with little or no increase at 28 days.

The tests recommended by the board are those for *fineness, specific gravity, soundness* or constancy of volume in setting, *time of setting, tensile strength,* for Portland cement, the specific-gravity and soundness tests being omitted for natural hydraulic cements. Bonuses for tests above a fixed point are said to be likely to result in unsoundness in ways not quickly detected.

The Engineer board goes into great detail in the matter of manipulation of cements for tests as follows:

Fineness.—Place 100 parts (denominations determined by subdivisions of the weighing machine used) by weight on a sieve with 100 holes to the linear inch, woven from brass wire No. 40, Stubb's wire gauge; sift by hand or mechanical shaker until cement ceases to pass through.

The weight of the material passing the sieve plus the weight of the dust lost in air, expressed in hundredths of the original weight, will express the percentage of fineness. In order to determine this percentage the residue on the sieve should be weighed.

It is only the impalpable dust that possesses cementitious value. Fineness of grinding is therefore an essential quality in cements to be mixed with sand. The residue on a sieve of 10 meshes to the inch is of no cementitious value, and even the grit retained on a sieve of 40,000 openings to the square inch is of small value. The degree of fineness prescribed in these specifications (92 per cent.) for Portland through a sieve of 10,000 meshes to the square inch is quite commonly attained in high-grade American cements, but rarely in imported brands.

Specific Gravity.—The standard temperature for specific gravity determinations is 62 degrees F., but for cement testing temperatures may vary between 60 degrees and 80 degrees F. without affecting results more than the probable error

in the observation. Use any approved form of volumenometer or specific gravity bottle, graduated to cubic centimeters with decimal subdivisions. Fill instrument to zero of the scale with benzine, turpentine, or some other liquid having no action upon cements. Take 100 grams of sifted cement that has been previously dried by exposure on a metal plate for 20 minutes to a dry heat of 212 degrees F., and allow it to pass slowly into the fluid of the volumenometer, taking care that the powder does not stick to the sides of the graduated tube above the fluid and that the funnel through which it is introduced does not touch the fluid. Read carefully the volume of the displaced fluid to the nearest fraction of a cubic centimeter. Then the approximate specific gravity will be represented by 100 divided by the displacement in cubic centimeters. The operation requires care.

Setting Quality and Soundness.—The quantity of water and the temperature of water and air affect the time of setting. The specifications contemplate a temperature varying not more than 10 degrees from 62 degrees F., and quantities of water given herein: For Portland cements use 26 per cent. of water; for puzzolan cements use 30 per cent. of water. Mix thoroughly for five minutes, vigorously rubbing the mixture under pressure; time to be estimated from moment of adding water and to be considered of importance.

Make on glass plates two cakes from the mixture about 3 ins. in diameter, ½ in. thick at middle, and drawn to thin edges, and cover them with a damp cloth or place them in a tight box not exposed to currents of dry air. At the end of the time specified for initial set apply the needle 1-12 in. diameter weighted to ¼-lb. to one of the cakes. If an indentation is made the cement passes the requirement for initial setting, if no indentation is made by the needle it is too quick setting. At the end of the time specified for "final set" apply the needle 1-24 in. diameter loaded to 1 lb. The cement cake should not be indented.

Expose the two cakes to air under damp cloth for 24 hours. Place one of the cakes, still attached to its plate, in water for 28 days; the other cake immerse in water at about 70 degrees temperature supported in a rack above the bottom of the receptacle; raise the water gradually to the boiling point and maintain this temperature for six hours and then let the water with cake immersed cool. Examine the cakes at the proper time for evidences of expansion and distortion. Should the boiled cake become detached from the plate by twisting and warping or show expansion cracks the cement may be rejected, or it may await the result of 28 days in water. If the fresh-

water cake shows no evidence of swelling, the cement may be used in ordinary work in air or fresh water for lean mixtures. If distortion or expansion cracks are shown on the fresh-water cake, the cement should be rejected. Of two or more cements offered, all of which will stand the fresh-water cake tests for soundness, the cements that will stand the boiling tests also are to be preferred.

Tensile Strength—Neat Tests.—Use unsifted cements. Place the amount to be mixed on a smooth, non-absorbent slab; make a crater in the middle sufficient to hold the water; add nearly all the water at once, the remainder as needed; mix thoroughly by turning with the trowel, and vigorously rub or work the cement for five minutes.

Place the mold on a glass or slate slab. Fill the mold with consecutive layers of cement, each when rammed to be ¼-in. thick. Tap each layer 30 taps with a soft brass or copper rammer weighing 1 lb. and having a face ¾-in. diameter or 7-16-in. square with rounded corners. The tapping or ramming is to be done as follows: While holding the forearm and wrist at a constant level, raise the rammer with the thumb and forefinger about ½-in. and then let it fall freely, repeating the operation until the layer is uniformly compacted by 30 taps.

This method is intended to compact the material in a manner similar to actual practice in construction, when a metal rammer is used weighing 30 lbs., with a circular head 5 ins. in diameter, falling about 8 ins. upon layers of mortar or concrete 3 ins. thick. The method permits comparable results to be obtained by different observers.

After filling the mold and ramming the last layer, strike smooth with the trowel, tap the mold lightly in a direction parallel to the base plate to prevent adhesion to the plate, and cover for 24 hours with a damp cloth. Then remove the briquette from the mold and immerse in fresh water, which should be renewed twice a week for the specified time if running water is not available for a slow current. If molds are not available for 24 hours, remove from the molds after final set, replacing the damp cloth over the briquettes. In removing briquettes before hard-set great care should be exercised. Hold the mold in the left hand and, after loosening the latch, tap gently the sides of the mold until they fall apart. Place the briquettes face down in the water trough.

For neat tests of Portland cement use 20 per cent. of water by weight. For neat tests of puzzolan cement use 18 per cent. of water by weight. For neat tests of natural cement use 30 per cent. of water by weight. Nearly all this water is

retained by Portland cement, whereas only about one-third of the gauging water is retained by puzzolan or natural cements; from this it follows that an apparent condition of plasticity or fluidity that ultimately little injures Portland paste, very seriously injures puzzolan or natural mortars and concretes by leaving a porous texture on the evaporation of the surplus water.

Sand Tests.—The proportions 1 cement to 3 sand are to be used in tests of puzzolan and Portland, and 1 cement to 1 sand in tests of natural or Rosendale cements. Crushed quartz sand, sifted to pass a standard sieve with 20 meshes per lin. in. and to be retained on a standard sieve with 30 meshes to the inch, is to be used.

After weighing carefully, mix dry the cement and sand until the mixture is uniform, add the water as in neat mixtures, and mix for five minutes by triturating or rubbing together the constituents of the mortar. This may be done under pressure with a trowel or by rubbing between the fingers, using rubber gloves. The rubbing together seems necessary to coat thoroughly the facets of the sand with the cement paste.

It is found that prolonged rubbing, when not carried beyond the time of initial set, results in higher tests. Five minutes is the time of mixing quite generally adopted in European specifications. The briquettes are to be made as prescribed for neat mixtures.

Portland cements require water from 11 to 12 per cent. by weight of constituent sand and cement for maximum strength in tested briquettes; puzzolan, about 9 to 10 per cent., and natural, about 15 to 17 per cent. Mixtures that at first appear too dry for testing purposes often become more plastic under the prolonged working required herein.

In general, about four briquettes constitute the maximum number that may be made well within the time required for initial setting of moderately slow-setting cements. Three such batches of sand mixtures should be made, and one briquette of each batch may be broken at 7 and 28 days, giving three tests at each period. At least one batch of neat cement briquettes should be made.

If the first briquette broken at each date fulfills the minimum requirements of these specifications, it is not necessary to break others, which may be reserved for long-time tests. If the first briquette does not pass the test for tensile strength, then briquettes may be broken at seven days, and the remaining six reserved for 28-day tests. The highest result from any sample is to be taken as the strength of the sample

when the break is at the least section of briquette.

If, on the 28-day tests, the cement not only more than fulfills the minimum requirements of these specifications, but also shows unusual gain in strength, it may still be accepted if the other tests are satisfactory, notwithstanding a low seven-day test, if early strength is not a matter of importance. Such cements are likely to be permanent.

For a batch of four briquettes, the following quantities are suggested as in accord with these specifications. Water is measured by fluid-ounce volumes, not by weight, temperature varying not more than 10 degrees from 62 degrees F.

Portland Cement.—Neat: 20 ozs. of cement, 4 ozs. of water. Mix wet five minutes.

Sand: 15 ozs. sand, 5 ozs. cement, 2½ ozs. water. Mix thoroughly dry; then mix wet five minutes.

Puzzolan Cement.—Neat: 20 ozs. cement, 3¾ ozs. water. Mix wet five minutes.

Sand: 15 ozs. sand, 5 ozs. cement, 2 ozs. water. Mix thoroughly dry; then mix wet five minutes.

Natural Cement.—Neat: 20 ozs. cement, 6 ozs. water. Mix thoroughly dry; then mix wet five minutes.

Sand: 10 ozs. cement, 10 ozs. sand, 3½ ozs. water. Mix dry; then wet for five minutes.

For measuring tensile strength, a machine that applies the stress automatically at a uniform rate is preferable to one controlled entirely by hand. These specifications for tensile strength contemplate the application of stress at the rate of 400 lbs. per minute to briquettes made as prescribed herein. A rate so rapid as to approximate a blow or so slow to approximate a continued stress will give very different results.

The tests for tensile strength are to be made immediately after taking from the water or while the briquettes are still wet. The temperature of the water during immersion should be maintained as nearly constant as practicable; not less than 50 degrees nor more than 70 degrees F.

The tests are to be made upon briquettes 1 in. sq. at place of rupture. The specifications contemplate the use of the form of briquette recommended by the committee of the American Society of Civil Engineers, held when tested by close-fitting metal clips, without rubber or other yielding contacts. The breaks considered in the tests are to be those occurring at the smallest section, 1 in. sq.

Simple Tests.—Tests of cement received upon a work in progress must often be of much simpler character than prescribed herein. Tests on the work are mainly to ascertain whether the article supplied is genuine cement, of a brand pre-

viously tested and accepted, and whether it is a reasonably sound and active cement that will set hard in the desired time, and give a good, hard mortar. Simple tests may give this information, and such should be multiplied whether or not more elaborate tests be made. Pats and balls of cement and mortar from the storehouse and mixing platform or machine should be frequently made. The setting or hardening qualities, as determined roughly by estimating time and by pressure of the thumbnail, should be observed; the hardness of the set and strength, by cracking the hardened pats or cakes between the fingers, and by dropping the balls from the height of the arm upon a pavement or stone and observing the result of the impact.

By placing the pats in water as soon as hardened sufficiently and raising the temperature to the boiling point for a few hours and observing the character and color of the fracture after sufficient immersion, information as to the character of the material, whether hydraulic, a Portland or puzzolan, whether too fresh or possibly "blowy," may be speedily and quite well ascertained without measuring instruments.

Many engineers and users of cements regard such simple tests, taken in connection with the weight and fineness of the cement and the apparent texture and hardness of the mortars and concretes in the work, sufficient field tests of a material of known repute. The more elaborate tests, described above, should be made in well-equipped laboratories by skilled cement testers.

Classification of Tests.—The tests to be made are of two classes: (1) Purchase tests on samples furnished by bidders to ascertain whether the bidder may be held on the sample to the delivery of suitable material, should his offer be accepted. (2) Acceptance tests on samples taken at random from deliveries, to ascertain whether the material supplied accords with the purchase sample, or is suitable for the purpose of the work, as stated in the specifications for cement supplies.

(1) *Purchase Tests.*—Under these specifications bids for Portland cements will be restricted to brands that have been approved after at least three years' exposure in successful use under similar conditions to those of the proposed work. This specification limits proposals to manufacturers of cements of established repute, and in so far lessens the dependence to be placed upon tests of single samples of cement in determining the probable quality of the cements offered, that sample packages may not be required with the proposals when the brand is known to the purchaser. When the cement is not known to the purchasing officer by previous use, a barrel of it should be

required as representing the quality of cement to be supplied. A full set of tests should be made from this sample, and subsequent deliveries be required to show quality at least equal to the sample.

In this connection it is advisable in districts where well-equipped laboratories have been established, that sample packages of the cements in use in that territory, as sold in the open market, be obtained and tested as occasion offers, to ascertain the characteristic qualities of the brands as commercial articles, the information to be used in subsequent purchases of cements.

When purchase samples are waived, acceptance tests should be based upon the known qualities of the brand, as shown by previous tests. The sample barrel should not be broken further than to take therefrom the necessary samples for testing. Afterwards it should be put away in a dry place and kept for further testing, should the results obtained be disputed.

(2) *Acceptance Tests.*—The tests to be made on cements delivered under contract depend not only on the extent, character, and importance of the work itself, but also on the time available between the delivery and the actual use of the material.

(a) On very important and extensive works, equipped with a testing laboratory and adequate storehouses, where cement may be kept at least 30 days before being required for use, full and elaborate tests should be made, keeping in view the fact that careful tests of few samples are more valuable than hurried tests of many samples.

(b) On active works of ordinary character, when time will not permit full tests, and on small works where the expenses of a laboratory are not justified, the tests must necessarily be limited to such reasonable precautions against the acceptance and use of unfit material as may be taken in the usually short interval between the receipt and use of the material.

Such conditions were in view in formulating the specification that proposals will be received from manufacturers of such cements only as have been proved by at least three years' use under similar conditions of exposure. Of the tests named in the specifications those for fineness, activity or hydraulicity, specific gravity, weight of packages, and accelerated tests for indications as to soundness, may be made within two days after the receipt of the material and with a very small outlay for instruments.

Cement of established repute, shown by specific gravity and fineness to be properly burnt and ground, or normal for the brand, that will set hard in reasonable time, the cakes snap-

ping with a clean fracture when broken between the fingers, and standing the tests above named, may be accepted and used with reasonable certainty of success. Nevertheless, packages taken at random from the deliveries should occasionally be set aside and samples taken therefrom sent to a testing laboratory for the more elaborate tests for tensile strength (and for soundness should the boiling tests not be conclusive). The final acceptance and payment for such cement as may not have been actually placed in the work should, by agreement, be made to depend upon such tests.

In all cases where cement has been long stored it should be carefully tested before use to ascertain whether it has deteriorated in strength.

Should the simple tests give unsatisfactory or suspicious results, then a full series of tests should be carefully made.

When Portland cement is in question the specific gravity and fineness should be made to guard against adulteration, and in all cases test weighings should be made to guard against short weights.

In cases where the amount of cement or the importance of the work will not justify the purchase of the simple apparatus required for the specific gravity, fineness, and boiling tests, the cement can be accepted on the informal tests mentioned herein, which require no apparatus whatever, but in such cases cements well known to the purchaser by previous use should be selected, and purchased directly from the manufacturer or his selling agent in order that responsibility for the cement may be fixed.

Certified tests by professional inspectors, made as prescribed herein on samples taken from the cement to be shipped to the work, in a manner analogous to that customary among engineers in the purchase of structural steel and iron, may be required in such cases.

Sampling.—The entire package from parts of which tests are to be made is to be regarded as the sample tested. It should be marked with a distinctive mark that must also be applied to any part tested. The package should be set aside and protected against deterioration until all results from tests made from it are reached and accepted by both parties to the contract for supplies.

Cement drawn from several sample packages should not be mixed or mingled, but the individuality of each sample package should be preserved.

In testing it should be borne in mind that a few tests from any sample, carefully made, are more valuable than many made with less care.

The amount of material to be taken for formal tests is indicated herein where weights of the constituents of four briquettes are given, to which should be added the amount necessary for the tests for specific gravity, activity, and soundness.

In extended tests the material should be taken from the sample package from the heads and center of barrel, and from the ends and center of bag, by such an instrument as is used by inspectors of flour. All material taken from the same sample package may be thoroughly mixed or mingled and the tests be made therefrom as showing the true character of the contents of the sample package.

In making formal tests at the work for acceptance of cement, sample packages should be taken at random from among sound packages. The number taken must depend upon the importance and character of the work, the available time, and the capacity of the permanent laboratory force. For tensile strength the tests with sand are considered the more important and should always be made. Tests neat should be made if time permits.

It is not necessary in any case on a large work to test more than 10 per cent. of the deliveries, even of doubtful cement, and a much less number of samples may be taken should no cause for distrust be revealed by the tests made. In very important work of small extent each package may be tested. A cement should be rejected if the samples show dangerous variation in quality or lack of care in manufacture and resulting lack of uniformity in the product without regard to the proportion of failures among samples tested.

In all cases in the use of cements the informal or simple tests of the character named herein should be constantly carried on. These constitute most valuable tests. Whenever any faulty material is indicated by such tests, elaborate tests should be at once instituted and should the fault be confirmed, the cement delivered and not used should be rejected and the use of the brand be discontinued.

Tests for Weight.—From time to time packages should be weighed in gross and afterwards the weight of neat cement and tare of the packages determined. If short weight of neat cement is indicated, a sufficient number of packages should be weighed and the average net weight per package ascertained with sufficient certainty to afford a satisfactory basis of settlement.

Records.—For tests by professional laboratories no general requirements as to records seem to be necessary. Each laboratory has its own blanks with certificate, and if a copy of the specifications be sent with the samples, the record returned

should be sufficient. For records of formal tests on the work, or in a district laboratory, blank forms should be used. It is desirable to have the specification requirements stated on the form. Notations should be adopted to show for each test that the cement passed or failed or that the test was not made. No inference should be drawn from the lack of any entry other than that the recorder has neglected his duty.

Silica Cement or Sand Cement.—This is a patented article manufactured by grinding together silica or clean sand with Portland cement, by which process the original material is made extremely fine and its capacity to cover surfaces of concrete aggregates is much increased. The sand is an adulteration, but on account of the extreme fineness of the product it serves to make mortar or concrete containing a given proportion of pure cement much more dense, the fine material being increased in volume.

The increase in cementing capacity due to the fine grinding of the cement constituent offsets, in great degree, the effects of the sand adulteration, so that sand cement made from equal weights of cement and sand approximates in tensile strength to the neat cement and the material is sold as cement.

The extreme fine grinding also improves cement that contains expansives, but nevertheless sand cement should not be purchased in the market, but should be made on the work from approved materials, if used for other purposes than for grouting, for which it is peculiarly adapted.

Whether this material should be used in important works for mortar and concrete, the board considers a question of cost and expediency.

Over against the saving in cement may be placed the royalty on a patented article, the cost of the plant and of manufacture, the inconvenience of attaching a manufacturing establishment to a work under construction, and other elements bearing not only on first cost of cementing material but also involving the element of time. When cement is high priced, means of transportation limited, labor, sand, and concrete materials cheap and abundant, the conditions may justify the use of sand cement on economic grounds. In any case, the cement from which the product is made should be tested precisely as other cements.

Slag Cement.—This term is applied to cement made by intimately mixing by grinding together granulated blast-furnace slag of a certain quality and slaked lime, without calcination subsequent to the mixing. This is the only cement of the puzzolan class to be found in our markets (often branded as Portland), and as true Portland cement is now made having slag

for its hydraulic base, the term "slag cement" should be dropped and the generic term puzzolan be used in advertisements and specifications for such cements.

Puzzolan cement made from slag is characterized physically by its light lilac color; the absence of grit attending fine grinding and the extreme subdivision of its slaked lime element; its low specific gravity (2.6 to 2.8) compared with Portland (3 to 3.5); and by the intense bluish green color in the fresh fracture after long submersion in water, due to the presence of sulphides, which color fades after exposure to dry air.

The oxidation of sulphides in dry air is destructive of puzzolan cement mortars and concretes so exposed. Puzzolan is usually very finely ground, and when not treated with soda sets more slowly than Portland. It stands storage well, but cements treated with soda to quicken setting become again very slow setting from the carbonization of the soda (as well as the lime) after long storage.

Puzzolan cement properly made contains no free or anhydrous lime, does not warp or swell, but is liable to fail from cracking and shrinking (at the surface only) in dry air.

Mortars and concretes made from puzzolan approximate in tensile strength similar mixtures of Portland cement, but their resistance to crushing is less, the ratio of crushing to tensile strength being about 6 or 7 to 1 for puzzolan and 9 to 11 to 1 for Portland. On account of its extreme fine grinding puzzolan often gives nearly as great strength in 3 to 1 mixtures as neat.

Puzzolan permanently assimilates but little water compared with Portland, its lime being already hydrated. It should be used in comparatively dry mixtures well rammed, but while requring little water for chemical reactions, it requires for permanency in the air constant or continuous moisture.

Proper Uses of Puzzolan Cement.—Puzzolan cement never becomes extremely hard like Portland, but puzzolan mortars and concrete are tougher or less brittle than Portland. The cement is well adapted for use in sea water, and generally in all positions where constantly exposed to moisture, such as in foundations of buildings, sewers and drains, and underground works generally, and in the interior of heavy masses of masonry or concrete. It is unfit for use when subjected to mechanical wear, attrition, or blows. It should never be used where it may be exposed for long periods to dry air, even after it has well set. It will turn white and disintegrate, due to the oxidation of its sulphides at the surface under such exposure.

OTHER TESTS.

The following points are not touched in the foregoing reports:

Microscopical Tests.—These are generally considered to be unnecessary, but they are of some value in determining adulterants and the character of the grains of cement, thus giving some check on burning and grinding. From a hand-microscope to magnifying powers of 80 to 600 diameters are recommended by various engineers.

Compressive Strength.—The foregoing report dismisses tests of compressive strength as unnecessary, "the ratio of compressive to tensile strength of the same class of cements being quite uniform" and the tensile test being much more easily made. The most prominent German manipulators of cement do not report this uniformity, and in recent discussions before technical societies are reported to consider compressive tests more important than tensile tests, though recommending that both be made. Some American engineers recommend them, a few depending upon them to the exclusion of those of tensile and transverse strength. The opinion seems to be general that the tests can not be made in a temporary laboratory, must be made in permanent commercial or college laboratories having the necessary machines and experience. Too few have used the method to have any fixed idea as to form and dimensions of test pieces. All would treat the mortar the same as for tension tests. There are several methods of getting a true bearing in the press, truing with trowel, setting against glass and the use of sheets of lead, thick paper or cardboard, plaster of paris, or fine sand. All the prominent machines are mentioned, and the rate of applying the stress varies up to 1,000 pounds a minute.

Adulterations.—Microscopic examination may detect adulteration. Slag adulterant may be detected by stirring the cement into a mixture of methylene iodide and benzine. When allowed to stand the cement will settle to the bottom, with the slag on top. The density of the mixture must be carefully fixed at the desired amount, say 2.95, by adding the proper amount of benzine. Machines are made for tests of abrasion of cement and concrete. A number of other tests are proposed

for special purposes, but they need not be considered here, as the tests given are those which are of most value for commercial purposes, and those not mentioned are of little value unless made and interpreted by experts.

In a paper by Prof. W. K. Hatt before the Indiana Engineering Society occurs the following paragraph, indicating a method of detecting slag adulteration of cement:

The appearance of the slag cement is characterized by a delicate lilac color, in some cases almost white. When cement is made from slag by a process involving roasting, the cement is of a dark color like that of ordinary dark colored Portland. It has not the coarse or gritty feeling which characterizes most Portland cement. It works fat, sets slowly and passes ordinary tests of permanence of volume.

A pat of the cement exposed to the air has to be well covered to prevent the surface from cracking. After drying out, it will exhibit discolorations, yellowish or brown, whereas the pat hardened under water will not exhibit such discolorations. The characteristic color of the fracture of a water-hardened briquette is green, but when the briquette dries out the fracture becomes white. The writer has noticed this green color with a subsequent change to white in the case of a well known Portland cement, and also the discolorations in the pat, indicating slag adulteration. The green color is due to the presence in slag cement of sulphide of iron or sulphide of calcium. This sulphide becomes oxidized on exposure to the air and changes color. Slag cements usually contain from 1 to 1½ per cent. of sulphides. It is this tendency to oxidization on exposure to air which is destructive to mortar made of slag cements containing an excess of sulphides and makes it necessary to use the product in underground situations or the interior of thick walls. A parallel test of briquettes hardened in air and water should be made to check up presence of sulphides. This disintegration does not occur in case of all slag cements. It is not a necessary defect.

Accelerated Tests.—Other accelerated tests than those given above will be found in forms of specification in the following chapter. In the methods proposed by Prof. Tetmajer, the pats are put in cold water as soon as possible after gauging, the water is raised in about one hour to boiling temperature and the boiling is continued for three hours. Some slow-setting cements can not be put into the water until they have set. The pats should not have thin edges but should be rolled

into balls and carefully flattened. Le Chatelier makes the pats in cylindrical form, 3 centimeters long and the same diameter. An American would make the dimensions each one inch. Needles are set in each end and observations on the distance apart of their points show the amount of swelling. The water is raised to boiling point in fifteen to thirty minutes and maintained there for six hours. The pats are allowed to cool before measurements are taken. The pats are allowed to set and the test is made within twenty-four hours after the time of final set. Other accelerated tests use moist hot air, steam and hot water, steam or water under pressure, dry closets under a temperature above boiling point, and a gas flame. The steam and hot water tests are most uniform and satisfactory and the boiling test is much the easiest of application.

Bending, adhesion, abrasion, resistance to freezing and resistance to action of sea water are all advised by a few experts, but there are no settled opinions as to their general value and the methods of making them.

SPECIFICATIONS FOR CEMENT.

The general principles upon which specifications for the acceptance or rejection of cement should be prepared may well be stated, and the practical application of these principles exemplified by selections from various specifications in use in various parts of the country. The great variations in specifications for cement for the same uses would seem to be due largely to the failure to recognize such principles, though, when stated, they seem to be axiomatic.

The cement should be suited to the work in which it is to be used. This will decide whether natural hydraulic, puzzolan, or Portland cement shall be used and the grade of the latter. Economy should be one of the elements considered and may turn the decision to a natural cement in one locality while some grade of Portland cement would be used in another. The decision regarding the cement to be used affects the specifications for mortar and concrete also.

The exposure of the work to the weather or its protection from external conditions by position in the interior of piers or foundations or in rock or deep excavations under constant conditions of temperature, moisture, etc., will be prominent in deciding what specifications to adopt for the cement to be used.

For external work the conditions of variation in temperature, drainage, possibility of shocks, blows and abrasions, appearance, determine the grade of Portland cement to be used. Here, too, the specifications for mortar and concrete are closely connected with the specifications for cement.

In cases of joint action of concrete with other materials, as in reinforced concrete, fireproofing or other combination structures, other qualities than the tensile or compressive strength may make the decision.

Cement for mortar for laying stone must often be selected for its non-staining qualities.

The rate of setting is freqquently a prime factor in making the decision, especially in sidewalk, curb and facing work, and in structures under water.

STANDARD SPECIFICATIONS FOR CEMENT, ADOPTED BY THE AMERICAN SOCIETY FOR TESTING MATERIALS.

1. *General Conditions.*—All cement shall be inspected.

2. Cement may be inspected either at the place of manufacture or on the work.

3. In order to allow ample time for inspecting and testing, the cement should be stored in a suitable weather-tight building having the floor properly blocked or raised from the ground.

4. The cement shall be stored in such a manner as to permit easy access for proper inspection and identification of each shipment.

5. Every facility shall be provided by the contractor and a period of at least twelve days allowed for the inspection and necessary tests.

6. Cement shall be delivered in suitable packages with the brand and name of manufacturer plainly marked thereon.

7. A bag of cement shall contain 94 pounds of cement net. Each barrel of Portland cement shall contain 4 bags, and each barrel of natural cement shall contain 3 bags of the above net weight.

8. Cement failing to meet the seven-day requirements may be held awaiting the results of the twenty-eight day tests before rejection.

9. All tests shall be made in accordance with the methods proposed by the Committee on Uniform Tests of Cement of the American Society of Civil Engineers, presented to the Society January 21, 1903, and amended January 20, 1904, with all subsequent amendments thereto. (See addendum to these specifications.)

10. The acceptance or rejection shall be based on the following requirements:

11. NATURAL CEMENT.—*Definition.* This term shall be applied to the finely pulverized product resulting from the calcition of an argillaceous limestone at a temperature only sufficient to drive off the carbonic acid gas.

12. *Specific Gravity.*—The specific gravity of the cement thoroughly dried at 100 degrees C., shall be not less than 2.8.

13. *Fineness.*—It shall leave by weight a residue of not more than 10 per cent. on the No. 100, and 30 per cent. on the No. 200 sieve.

14. *Time of Setting.*—It shall develop initial set in not less than ten minutes, and hard set in not less than thirty minutes, nor more than three hours.

15. *Tensile Strength.*—The minimum requirements for tensile strength for briquettes one inch square in cross section

shall be within the following limits, and shall show no retrogression in strength within the periods specified:*

Age.	*Neat Cement.*	*Strength.*
24 hours in moist air		50-100 lbs.
7 days (1 day in moist air, 6 days in water)		100-200 lbs.
28 days (1 day in moist air, 27 days in water)		200-300 lbs.
	One Part Cement, Three Parts Standard Sand.	
7 days (1 day in moist air, 6 days in water)		25- 75 lbs.
28 days (1 day in moist air, 27 days in water)		75-150 lbs.

16. *Constancy of Volume.*—Pats of neat cement about three inches in diameter, one-half inch thick at centre, tapering to a thin edge, shall be kept in moist air for a period of twenty-four hours.

(*a*) A pat is then kept in air at normal temperature.

(*b*) Another is kept in water maintained as near 70 degrees F. as practicable.

17. These pats are observed at intervals for at least 28 days, and, to satisfactorily pass the tests, should remain firm and hard and show no signs of distortion, checking, cracking or disintegrating.

18. Portland Cement.—*Definition.* This term is applied to the finely pulverized product resulting from the calcination to incipient fusion of an intimate mixture of properly proportioned argillaceous and calcareous materials, and to which no addition greater than 3 per cent. has been made subsequent to calcination.

19. *Specific Gravity.*—The specific gravity of the cement, thoroughly dried at 100 degrees C., shall be not less than 3.10.

20. *Fineness.*—It shall leave by weight a residue of not more than 8 per cent. on the No. 100, and not more than 25 per cent. on the No. 200 sieve.

21. *Time of Setting.*—It shall develop initial set in not less than thirty minutes, but must develop hard set in not less than one hour, nor more than ten hours.

22. *Tensile Strength.*—The minimum requirements for tensile strength for briquettes one square inch in section shall be within the following limits, and shall show no retrogression in strength within the periods specified.**

Age.	*Neat Cement.*	*Strength.*
24 hours in moist air		150-200 lbs.
7 days (1 day in moist air, 6 days in water)		450-550 lbs.
28 days (1 day in moist air, 27 days in water)		550-650 lbs.

*For Example—The minimum requirement for the 24 hour neat cement test should be some value within the limits of 50 and 100 pounds, and so on for each period stated.

**For Example—The minimum requirement for the 24 hour neat cement test should be some value within the limits of 150 and 200 pounds, and so on for each period stated.

One Part Cement, Three Parts Standard Sand.

7 days (1 day in moist air, 6 days in water) . . . . . . 150-200 lbs.
28 days (1 day in moist air, 27 days in water) . . . . . . 200-300 lbs.

23. *Constancy of Volume.*—Pats of cement about three inches in diameter, one-half inch thick at the centre, and tapering to a thin edge, shall be kept in moist air for a period of twenty-four hours.

(a) A pat is then kept in air at normal temperature and observed at intervals for at least 28 days.

(b) Another pat is kept in water maintained as near 70 degrees F. as practicable, and observed at intervals for at least 28 days.

(c) A third pat is exposed in any convenient way in an atmosphere of steam, above boiling water, in a loosely closed vessel for five hours.

24. These pats, to satisfactorily pass the requirements, shall remain firm and hard and show no signs of distortion, checking, cracking or disintegrating.

25. *Sulphuric Acid and Magnesia.*—The cement shall not contain more than 1.75 per cent. of anhydrous sulphuric acid (SO_3), nor more than 4 per cent. of magnesia (MgO).

SPECIFICATIONS OF THE CORPS OF ENGINEERS U. S. ARMY.

The great variations in requirements for cement upon work under various officers of the Corps of Engineers of the U. S. Army, shown in a table in the first edition of this book, have been eliminated by referring the matter to a commission consisting of Major William L. Marshall, Major Smith S. Leach and Captain Spencer Cosby, whose report is given in No. 28 of the Professional Papers of the Corps of Engineers U. S. Army. The methods recommended for use in making tests have been given in a preceding chapter. The specifications for cement follow. The first specification is for American Portland cement.

(1) The cement shall be an American Portland, dry and free from lumps. By a Portland cement is meant the product obtained from the heating or calcining up to incipient fusion of intimate mixtures, either natural or artificial, of argillaceous with calcareous substances, the calcined product to contain at least 1.7 times as much of lime, by weight, as of the materials which give the lime its hydraulic properties, and to be finely pulverized after said calcination, and thereafter addition or substitution for the purpose only of regulating certain properties of technical importance to be allowable

to not exceeding 2 per cent. of the calcined product.

(2) The cement shall be put up in strong, sound barrels, well lined with paper, so as to be reasonably protected against moisture, or in stout cloth or canvas sacks. Each package shall be plainly labeled with the name of the brand and of the manufacturer. Any package broken or containing damaged cement may be rejected or accepted as a fractional package, at the option of the United States agent in local charge.

(3) Bidders will state the brand of cement which they propose to furnish. The right is reserved to reject a tender for any brand which has not established itself as a high-grade Portland cement and has not for three years or more given satisfaction in use under climatic conditions of exposure of at least equal severity to those of the work proposed.

(4) Tenders will be received only from manufacturers or their authorized agents.

(The following paragraph will be substituted for paragraphs 3 and 4 above when cement is to be furnished and placed by the contractor.:

No cement will be allowed to be used except established brands of high-grade Portland cement which have been made by the same mill and in successful use under similar climatic conditions to those of the proposed work for at least three years.)

(5) The average weight per barrel shall not be less than 375 pounds net. Four sacks shall contain one barrel of cement. If the weight, as determined by test weighings, is found to be below 375 pounds per barrel, the cement may be rejected, or, at the option of the engineer officer in charge, the contractor may be required to supply, free of cost to the United States, an additional amount of cement equal to the shortage.

(6) Tests may be made of the fineness, specific gravity, soundness, time of setting and tensile strength of the cement.

(7) *Fineness.*—Ninety-two per cent. of the cement must pass through a sieve made of No. 40 wire, Stubb's gauge, having 10,000 openings per square inch.

(8) *Specific Gravity.*—The specific gravity of the cement, as determined from a sample which has been carefully dried, shall be between 3.10 and 3.25.

(9) *Soundness.*—To test the soundness of the cement, at least two pats of neat cement mixed for five minutes with 20 per cent. of water by weight shall be made on glass, each pat about three inches in diameter and one-half inch thick at the center, tapering thence to a thin edge. The pats are to be

kept under a wet cloth until finally set, when one is to be placed in fresh water for twenty-eight days. The second pat will be placed in water which will be raised to the boiling point for six hours, then allowed to cool. Neither should show distortion or cracks. The boiling test may or may not reject, at the option of the engineer officer in charge.

(10) *Time of Setting.*—The cement shall not acquire its initial set in less than forty-five minutes and must have acquired its final set in ten hours.

(The following paragraph will be substituted for the above in case a quick-setting cement is desired:

The cement shall not acquire its initial set in less than twenty or more than thirty minutes, and must have acquired its final set in not less than forty-five minutes, nor in more than two and one-half hours.)

The pats made to test the soundness may be used in determining the time of setting. The cement is considered to have acquired its initial set when the pat will bear, without being appreciably indented, a wire one-twelfth inch in diameter loaded to weigh one-fourth pound. The final set has been acquired when the pat will bear, without being appreciably indented, a wire one twenty-fourth inch in diameter loaded to weigh one pound.

(1) *Tensile Strength.*—Briquettes made of neat cement after being kept in air for twenty-four hours under a wet cloth, and the balance of the time in water, shall develop tensile strength per square inch as follows:

After seven days, 450 pounds; after twenty-eight days, 540 pounds.

Briquettes made of 1 part cement and 3 parts standard sand, by weight, shall develop tensile strength per square inch as follows:

After seven days, 140 pounds; after twenty-eight days, 220 pounds.

(In case quick-setting cement is desired, the following tensile strengths shall be substituted for the above:

Neat briquettes: After seven days, 400 pounds; after twenty-eight days, 480 pounds.

Briquettes of 1 part cement to 3 parts standard sand: After seven days, 120 pounds; after twenty-eight days, 180 pounds.)

(12) The highest result from each set of briquettes made at any one time is to be considered the governing test. Any cement not showing an increase of strength in the twenty-eight-day tests over seven-day tests will be rejected.

(13) When making briquettes neat cement will be mixed

with 20 per cent. of water by weight, and sand and cement with $12\frac{1}{2}$ per cent. of water by weight. After being thoroughly mixed and worked for five minutes, the cement or mortar will be placed in the briquette mold in four equal layers, and each layer rammed and compressed by thirty blows of a soft brass or copper rammer three-quarters of an inch in diameter (or seven-tenths of an inch square, with rounded corners), weighing 1 pound. It is to be allowed to drop on the mixture from a height of about half an inch. When the ramming has been completed, the surplus cement shall be struck off and the final layer smoothed with a trowel held almost horizontal and drawn back with sufficient pressure to make its edge follow the surface of the mold.

(14) The above are to be considered the minimum requirements. Unless a cement has been recently used on work under this office, bidders will deliver a sample barrel for test before the opening of bids. If this sample shows higher tests than those given above, the average of tests made on subsequent shipments must come up to those found with the sample.

(15) A cement may be rejected in case it fails to meet any of the above requirements. An agent of the contractor may be present at the making of the tests, or, in case of the failure of any of them, they may be repeated in his presence. If the contractor so desires, the engineer officer in charge may, if he deem it to the interest of the United States, have any or all of the tests made or repeated at some recognized standard testing laboratory in the manner herein specified. All expenses of such tests to be paid by the contractor. All such tests shall be made on samples furnished by the engineer officer from cement actually delivered to him.

Then follow specifications for natural hydraulic cement.

(1) The cement shall be freshly packed natural or Rosendale, dry, and free from lumps. By natural cement is meant one made by calcining natural rock at a heat below incipient fusion, and grinding the product to a powder.

(2) The cement shall be put up in strong, sound barrels, well lined with paper so as to be reasonably protected against moisture, or in stout cloth or canvas sacks. Each package shall be plainly labeled with the name of the brand and of the manufacturer. Any package broken or containing damaged cement may be rejected, or accepted as a fractional package, at the option of the United States agent in local charge.

(3) Bidders will state the brand of cement which they propose to furnish. The right is reserved to reject a tender for

any brand which has not given satisfaction in use under climatic or other conditions of exposure of at least equal severity to those of the work proposed.

(4) Tenders will be received only from manufacturers or their authorized agents.

(The following paragraph will be substituted for paragraphs 3 and 4 above when cement is to be furnished and placed by the contractor.:

No cement will be allowed to be used except established brands of high-grade natural cement which have been in successful use under similar climatic conditions to those of the proposed work.)

(5) The average net weight per barrel shall not be less than 30 pounds. (West of the Allegheny Mountains this may be 265 pounds.) . . . sacks of cement shall have the same weight as 1 barrel. If the average net weight, as determined by test weighings, is found to be below 300 pounds (265 pounds) per barrel, the cement may be rejected, or, at the option of the engineer officer in charge, the contractor may be required to supply free of cost to the United States an additional amount of cement equal to the shortage.

(6) Tests may be made of the fineness, time of setting, and tensile strength of the cement.

(7) *Fineness.*—At least 80 per cent. of the cement must pass through a sieve made of No. 40 wire, Stubb's gauge, having 10,000 openings per square inch.

(8) *Time of Setting.*—The cement shall not acquire its initial set in less than twenty minutes and must have acquired its final set in four hours.

(9) The time of setting shall be determined from a pat of neat cement mixed for five minutes with 30 per cent. of water by weight and kept under a wet cloth until finally set. The cement is considered to have acquired its initial set when the pat will bear, without being appreciably indented, a wire one-twelfth inch in diameter loaded to weigh one-fourth pound. The final set has been acquired when the pat will bear, without being appreciably indented, a wire one twenty-fourth inch in diameter loaded to weigh 1 pound.

(10) *Tensile Strength.*—Briquettes made of neat cement shall develop the following tensile strengths per square inch, after having been kept in air for twenty-four hours under a wet cloth and the balance of the time in water:

At the end of seven days, 90 pounds; at the end of twenty-eight days, 200 pounds.

Briquettes made of one part cement and one part standard

sand, by weight, shall develop the following tensile strengths per square inch:

After seven days, 60 pounds; after twenty-eight days, 150 pounds.

(11) The highest results from each set of briquettes made at any one time is to be considered the governing test. Any cement not showing an increase of strength in the twenty-eight-day tests over the seven-day tests will be rejected.

(12) The neat cement for briquettes shall be mixed with 30 per cent. of water by weight, and the sand and cement with 17 per cent. of water by weight. After being thoroughly mixed and worked for five minutes the cement or mortar is to be placed in the briquette mold in four equal layers, each of which is to be rammed and compressed by thirty blows of a soft brass or copper rammer three-fourths of an inch in diameter (or seven-tenths of an inch square with rounded corners), weighing 1 pound. It is to be allowed to drop on the mixture from a height of about half an inch. Upon the completion of the ramming the surplus cement shall be struck off and the last layer smoothed with a trowel held nearly horizontal and drawn back with sufficient pressure to make its edge follow the surface of the mold.

(13) The above are to be considered the minimum requirements. Unless a cement has been recently used on work under this office, bidders will deliver a sample barrel for test before the opening of the bids. Any cement showing by sample higher tests than those given must maintain the average so shown in subsequent deliveries.

(14) A cement may be rejected which fails to meet any of the above requirements. An agent of the contractor may be present at the making of the tests, or, in case of the failure of any of them, they may be repeated in his presence. If the contractor so desires, the engineer officer may, if he deems it to the interest of the United States, have any or all of the tests made or repeated at some recognized standard testing laboratory in the manner above specified. All expenses of such tests shall be paid by the contractor, and all such tests shall be made on samples furnished by the engineer officer from cement actually delivered to him.

Puzzolan or slag cement is to fulfill the following conditions:

(1) The cement shall be a puzzolan of uniform quality, finely and freshly ground, dry, free from lumps, made by grinding together without subsequent calcination granulated blast-furnace slag with slaked lime.

(2) The cement shall be put up in strong sound barrels well

lined with paper, so as to be reasonably protected against moisture, or in stout cloth or canvas sacks. Each package shall be plainly labeled with the name of the brand and of the manufacturer. Any package broken or containing damaged cement may be rejected, or accepted as a fractional package, at the option of the United States agent in local charge.

(3) Bidders will state the brand of cement which they propose to furnish. The right is reserved to reject a tender for any brand which has not given satisfaction in use under climatic or other conditions of exposure of at least equal severity to those of the work proposed, and for any brand from cement works that do not make and test the slag used in the cement.

(4) Tenders will be received only from manufacturers or their authorized agents.

(The following paragraph will be substitued for paragraphs 3 and 4 above when cement is to be furnished and placed by the contractor.

No cement will be allowed to be used except established brands of high-grade puzzolan cement which have been in successful use under similar climatic conditions to those of the proposed work and which come from cement works that make the slag used in the cement.)

(5) The average weight per barrel shall not be less than 330 pounds net. Four sacks shall contain 1 barrel of cement. If the weight as determined by test weighings is found to be below 330 pounds per barrel, the cement may be rejected or, at the option of the engineer officer in charge, the contractor may be required to supply, free of cost to the United States, an additional amount of cement equal to the shortage.

(6) Tests may be made of the fineness, specific gravity, soundness, time of setting, and tensile strength of the cement.

(7) *Fineness.*—Ninety-seven per cent. of the cement must pass through a sieve made of No. 40 wire, Stubb's gauge, having 10,000 openings per square inch.

(8) *Specific Gravity.*—The specific gravity of the cement, as determined from a sample which has been carefully dried, shall be between 2.7 and 2.8.

(9) *Soundness.*—To test the soundness of cement, pats of neat cement mixed for five minutes with 18 per cent. of water by weight shall be made on glass, each pat about 3 inches in diameter and one-half inch thick at the center, tapering thence to a thin edge. The pats are to be kept under wet cloths until finally set, when they are to be placed in fresh

water. They should not show distortion or cracks at the end of twenty-eight days.

(10) The cement shall not acquire its initial set in less than forty-five minutes and shall acquire its final set in ten hours. The pats made to test the soundness may be used in determining the time of setting. The cement is considered to have acquired its initial set when the pat will bear, without being appreciably indented, a wire one-twelfth inch in diameter loaded to one-fourth pound weight. The final set has been acquired when the pat will bear, without being appreciably indented, a wire one-twenty-fourth inch in diameter loaded to 1 pound weight.

(11) *Tensile Strength.*—Briquettes made of neat cement, after being kept in air under a wet cloth for twenty-four hours and the balance of the time in water, shall develop tensile strengths per square inch as follows:

After seven days, 350 pounds; after twenty-eight days, 500 pounds.

Briquettes made of one part cement and three parts standard sand by weight shall develop tensile strength per square inch as follows:

After seven days, 140 pounds; afetr twenty-eight days, 220 pounds.

(12) The highest result from each set of briquettes made at any one time is to be considered the governing test. Any cement not showing an increase of strength in the twenty-eight-day tests over the seven-day tests will be rejected.

(13) When making briquettes neat cement will be mixed with 18 per cent. of water by weight, and sand and cement with 10 per cent. of water by weight. After being thoroughly mixed and worked for five minutes the cement or mortar will be placed in the briquette mold in four equal layers and each layer rammed and compressed by thirty blows of a soft brass or copper rammer, three-quarters of an inch in diameter or seven-tenths of an inch square, with rounded corners, weighing 1 pound. It is to be allowed to drop on the mixture from a height of about an inch. When the ramming has been completed the surplus cement shall be struck off and the final layer smoothed with a trowel held almost horizontal and drawn back with sufficient pressure to make its edge follow the surface of the mold.

(14) The above are to be considered the minimum requirements. Unless a cement has been recently used on work under this office, bidders will deliver a sample barrel for test before the opening of bids. If this sample shows higher tests than those given above, the average of tests made on subse-

quent shipments must come up to those found with the sample.

(15) A cement may be rejected in case it fails to meet any of the above requirements. An agent of the contractor may be present at the making of the tests, or, in case of the failure of any of them, they may be repeated in his presence. If the contractor so desires the engineer officer in charge may, if he deems it to the interest of the United States, have any or all of the tests made or repeated at some recognized testing laboratory in the manner herein specified, all expenses of such tests to be paid by the contractor. All such tests shall be made on samples furnished by the engineer officer from cement actually delivered to him.

The only criticisms of importance regarding the preceding specifications which have appeared are regarding the amount of water used in making briquettes, the specific gravity, and the fineness for the Pacific coast. Mr. E. Duryee calls attention to the fact that to produce the normal consistency of mortar according to Russian and other foreign specifications, the amount of water must be varied according to the brand of cement, and even according to the age of the shipment from which sample is taken, and that the amount required is almost always more than 20 per cent. by weight, sometimes running as high as 30 per cent.; that very finely ground cement may have a specific gravity of less than 3.1.

U. S. NAVY DEPARTMENT SPECIFICATIONS.

Quality.—The cement to be of the best grade or quality.

Aeration.—Contractor shall give a certificate to the effect that the cement furnished has been seasoned or subjected to aeration for at least thirty days before leaving the works.

Packing.—The cement is to be packed in strong and well coopered barrels, lined with moisture-proof paper. The gross weight of the barrels is not to be less than 400 pounds; the weight of the cement is not to be less than 375 pounds.

Storage.—Immediately upon receipt, the cement is to be stored in a dry, well-covered and well-ventilated place and thoroughly protected from the weather.

Chemical Analysis.—On every lot of eight hundred barrels or more, the contractor shall supply an abstract of the chemical analysis of a mixed sample of the cement taken from any ten barrels of the lot. Specific gravity shall not be less than 3.

Samples for Test.—Samples of the cement are to be taken from the interior of the barrels with a suitable instrument.

Samples are to be taken from every fifth barrel, in lots of twenty or more, up to one hundred barrels. If less than one hundred barrels are to be tested, the samples are to be taken from at least three barrels. The separate quantities so taken shall be mixed thoroughly together, while dry, and the compound regarded as the sample for test.

Fineness.—Ninety-five per cent. by weight must pass through a No. 100 sieve having 10,000 meshes per square inch, the wire to be No. 40 Stubb's wire gauge, and 75 per cent. by weight must pass through a No. 200 sieve having 40,000 meshes per square inch, the wire to be No. 48 Stubb's wire gauge.

Setting Qualities.—Cakes of the paste, mixed as specified in the following paragraph, are to be molded on glass; these cakes to be circular in shape, three inches in diameter, one-half inch thick in center and drawn down to one-eighth inch at circumference. One cake is to set in air, and one cake is to set immersed in water. Two wires are to be used to determine setting qualities: The first, called wire A, is to be one-twelfth inch in diameter at the lower extremity and loaded with ¼ lb. at the upper end; and the second, called wire B, is to be one twenty-fourth inch in diameter at the lower extremity and loaded with 1 lb. at the upper end. Cement will be considered as quick-setting if it bears needle A without making an indentation during any time between one hour and six hours after having been mixed. The slow-setting cement must have its final set at the end of eight hours—that is, it must bear needle B without being indented by it.

Neat Cement Paste for Test.—All neat cement for test is to be mixed on glass with clean, fresh water of a temperature between 60 degrees and 70 degrees F.; the quantity of the water to vary between 20 per cent. and 25 per cent. by weight of the quantity of cement used.

Change of Volume.—A small quantity of the same cement specified above is to be mixed with only sufficient water to give it the consistency of wet sand, and it is to be immediately pressed into a glass tube of about one-half inch in diameter. Within two or three days any swelling will be shown by the glass bursting; or shrinkage, by the cement becoming loose in tube; either defect is a cause for rejection of the cement.

Checking and Cracking.—Three cakes of neat cement are to be prepared as specified in paragraph for setting quality. One cake, after having set hard on the glass on which it was moulded, is to be placed in cold water and examined from time to time during a period covering seven or twenty-seven

days. If it warps, checks on surface, cracks at the edge, or leaves the glass, such defects are cause for the rejection of the cement. One cake is to be placed in air, and one cake in water kept at a temperature of 212 degrees for 24 hours and similarly examined.

Sand.—The sand that is to be mixed with the neat cement for compounding mortar briquettes for test shall be No. 4 standard crushed quartz, passing through a No. 20 sieve (400 meshes to the square inch), wire of No. 31 Stubb's wire gauge.

Making the Briquettes.—Neat Briquettes: moisten the cement with 20 per cent. to 22 per cent. of water, mixing and kneading it quickly by hand, using rubber gloves for protection. When thoroughly worked fill the molds at once, having first wiped them on the inside with an oily cloth to prevent sticking. Mortar briquettes: one part by weight of cement to three parts by weight of the kind of sand specified in the preceding section shall be thoroughly incorporated while dry and then moistened with 10 per cent. or 12 per cent. of water in the manner specified above for neat briquettes. Both the neat and mortar briquettes shall be prepared by the Bohme Hammer Apparatus, which is a tilt hammer with automatic action. The hammer is driven by a cam wheel of ten cams actuated by a simple gearing. The steel hammer weighs 4½ lbs., and when the intended number of blows has been delivered the mechanism is automatically checked, the proper setting having been made for this purpose before beginning the work. The number of blows for each briquette shall be 150. The briquettes while drying in air should be covered with a damp cloth to prevent rapid surface drying, and to conduce to a uniform set.

Tensile Strength.—The neat briquettes prepared as specified above, shall stand a minimum tensile strain per square inch, without breaking, as follows:

For 12 hrs. in air and 12 hrs. in water................200 lbs.
For 1 day in air and 6 days in water..................550 lbs.
For one day in air and 27 days in water..............650 lbs.

The mortar briquettes prepared as specified above, shall stand a minimum tensile strain per square inch, without breaking, as follows:

After 12 hrs. in air and 12 hrs. in water..............150 lbs.
After 1 day in air and 6 days in water................200 lbs.
After 1 day in air and 27 days in water..............250 lbs.

Notes.—The boiling water test is designed to ascertain the durability of the cement, and is intended to show in a few hours what would take a long period otherwise. This test is supposed to show whether an excess of free lime is in the

cement. Some cements stand well for short periods, but disintegrate after three or four months, due to an excess of free lime.

In making the mortar bricks, the sand and cement should be thoroughly mixed while dry, and then the specified percentage of water added quickly.

The neat tests are of less value than those of briquettes made of sand and cement. The fineness of cement is important; for the finer it is the more sand can be used with it.

Good cement should be a uniform bluish gray color throughout; yellow checks or places indicate an excess of clay or that the cement has not been sufficiently burned; and it is then probably a quick-setting cement of low specific gravity and deficient strength.

Cement that will stand a high test for seven days may have an excess of lime, which will cause it to deteriorate. The twenty-eight day test is, therefore, very useful.

The trip hammer machine for making briquettes removes all variability in their preparation.

The most dangerous feature in Portland cement is the presence of too much magnesia and an excess of free lime, the latter indicated by the cracks and distortions in the test cakes, and the former in the deficiency of tensile strength of the briquettes. Over 3 per cent. of magnesia is excessive and dangerous.

The cement that is to be made into briquettes and cakes shall not be sifted, but it is to be used exactly as it comes from the barrels.

Five briquettes should be broken to test the tensile strength, and the extra variation from the mean of the five should not be over 15 per cent.

The test for change of volume is very important, for expansion in any work into which the cement enters would be fatal to reliability.

The test cakes should be made by rolling the cement into balls and then flattening.

The expanding, cracking and disintegrating of the cement is technically called blowing.

If the cake at the end of three days in water shows no sign of cracking or disintegrating at the edges, it can be considered safe.

In examining cakes for cracks, the fine hair cracks found on the surface, that cross and recross each other, are not due to blowing, but are merely the result of changes of temperature. The cracks due to blowing are wedge shaped, running from the center and usually accompanied by a certain amount of disintegration, especially at the edges.

Either Fairbanks or Riehle machines should be used for breaking briquettes in a test for tensile strength.

The weight per barrel and the weight of barrel vary and the specification given above is a valuable one. Thus in 25 barrels of standard American and foreign cements the average weight of cement per barrel of the seven brands tested varied from 370 to 387 pounds, the weight of barrel varied from 21 to 29 pounds, and the weight of unbroken package varied from about 394 to 410 pounds.

SPECIFICATIONS OF RAILROADS.

For railroad work the specifications have heretofore been very discordant. Some sample specifications and abstracts from specifications for railroads in different parts of the country are given, showing the best practice for this class of work. The rapidly increasing use of Portland cement for railroad structures demanded material improvement in specifications, and such improvement has been quite marked in the last year or two.

The following are the specifications for cement of the engineering department of the New York Central & Hudson River railroad:

Tests.	*Natural Rock.*	*Portland.*
Sieve— No. 50 of 2,500 meshes per square inch of No. 35 Stubbs' wire gauge.	95 per cent. "fine"	97 per cent. "Fine"
Light Wire— Cement to bear $\frac{1}{12}$" diameter wire, weight 4 oz., without imprint, in not less than	25 minutes.	25 minutes.
Heavy Wire— Cement to bear $\frac{1}{24}$" diameter wire, weight 1 lb., without imprint, in not less than	50 minutes.	50 minutes.
Checking, Cracking and Hot Tests— Flat cakes or "pats" of stiff plastic neat cement paste, two to three inches diameter by half inch thickness, with thin edges to be immersed in water not less than two days.	Must not crack nor become contorted along the edges.	Shall withstand without cracking a temperature of steam or water at 212° Fahr. after 24 hours set in cold water.

Tensile Strength.—Standard briquettes of one square inch of breaking section. Stress applied at a uniform rate, from zero, of about 400 lbs. per minute.

Neat.	*Natural Rock.*	*Portland.*
1 hour in air 23 hours in water	60 lbs.	100 lbs.
24 hours in air 6 days in water	90 "	260 "
24 " 13 "	115 "	350 "
24 " 20 "	132 "	410 "
24 " 27 "	143 "	450 "
Average	108 lbs.	314 lbs.

Standard Sand.	*1 to 2.*	*1 to 3.*
1 hour in air 23 hours in water	27 lbs.	60 lbs.
24 hours in air 6 days in water	35 "	90 "
24 " 13 "	43 "	115 "
24 " 20 "	50 "	132 "
25 " 27 "	56 "	143 "
Average	42 lbs.	108 lbs.

Weight.	*Natural Rock.*	*Portland.*
1 barrel shall contain of neat cement, not less than	300 lbs.	386 lbs.

The following are selected from the standard specifications of the maintenance of way department of the Pennsylvania Railroad Company:

Sampling.—The cement for testing shall be selected by taking from each of six well-distributed barrels in each car-load received, sufficient cement to make five to ten briquettes; these six portions, after being thrown together and thoroughly mixed will be assumed to represent the average of the whole car-load.

Fineness.—Not more than 10 per cent. of any cement shall fail to pass through a No. 50 sieve (2,500 meshes per square inch, wire to be No. 35 Stubb's wire gauge), and not more than 10 per cent. of Portland cement shall fail to pass a No. 100 sieve.

Cracking.—Neat cement mixed to the consistency of stiff plastic mortar and made in the shape of flat cakes, 2 or 3 inches in diameter and one-half inch thick with thin edges, when hard enough shall be immersed in water for at least two days. If they crack along the edges or become contorted, the cement is unfit for use.

Tensile Strength.—The test for tensile strength shall be made with briquettes of standard form recommended by the Amercian Society of Civil Engineers, in molds furnished by the engineer of maintenance of way. They must have an average tensile strength not less than that given in the table below:

	1 Day	*1 Week.*	*4 Weeks.*
Natural Hydraulic Cement—			
Neat	70	95	150
1 sand to 1 cement	....	50	120
2 sand to 1 cement	....	30	60
American and Foreign Portland Cement—			
Neat	100	320	450
2 sand to 1 cement	....	120	175

Proportion of Water.—The proportion of water used in making briquettes varies with the fineness, age and other conditions of the cement and the temperature of the air, but is approximately as follows: Neat cement, Portland, 20 per cent. to 30 per cent.; 1 sand, 1 cement, about 15 per cent. total weight; 2 sand, 1 cement, about 12 per cent. total weight.

Mixing.—The cement and sand in proper proportions shall be mixed dry and all the water specified added at one time, the mixing to be as rapid as possible to secure a thorough mixture of the materials, and the mortar, when stiff and plastic, to be firmly pressed to make it solid in the molds without ramming, and struck off level.

Molding.—The molds to rest directly on glass, slate, or other non-absorbent material. As soon as hard enough, briquettes are to be taken from the molds and kept covered with a damp cloth until immersed. In the one-day test, briquettes shall remain on the slab for one hour after being removed from mold and twenty-three hours in water. In one week or more test, briquettes shall remain in air one day after being removed from molds and balance of time in water. Briquettes are to be broken immediately after being taken from the water. Stress to be applied at a uniform rate of 400 pounds per minute, starting each time at zero. No record to be taken of briquettes breaking at other than the smallest section.

Sand.—The sand used in test shall be clean, sharp, and dry, and be such as shall pass a No. 20 sieve (400 meshes per square inch, wire to be No. 28 Stubb's wire gauge), and to be caught on a No. 30 sieve (900 meshes per square inch, wire to be No. 31 Stubb's wire gauge).

Water.—Ordinary fresh, clean water having a temperature between 60 degrees and 70 degrees F., shall be used for the mixture and immersion of all samples.

Proportions.—The proportions of cement and sand and water shall in all cases be carefully determined by weight. In preparing briquettes for test, sufficient material is to be taken to make one briquette at a time, and enough of water added to make a stiff paste as above stated.

The temperature of the testing room shall not be below 47 degrees F.

For concrete work to take the place of stone masonry, Mr. V. K. Hendricks, now an engineer on the Baltimore & Ohio Railway, makes the following requirements in addition to those made above for ordinary work.

Portland Cement.—The cement shall be a true Portland cement, made by calcining a proper mixture of calcareous and clayey earths, and if desired a certified statement shall be furnished of the chemical composition of the cement, and the raw materials from which it is manufactured. Without written authority no Portland cement will be accepted which contains more than two per cent. of magnesia in any form.

The fineness shall be such that at least ninety-nine per cent. shall pass through a standard brass cloth sieve of 50 meshes per linear inch, at least ninety per cent. shall pass through a sieve of 100 meshes per linear inch, and at least seventy per cent. shall pass through a sieve of 200 meshes per linear inch.

Samples for testing may be taken from each and every barrel delivered.

Specimens prepared from neat cement shall after seven days develop a tensile strength of not less than 450 pounds per square inch. Specimens prepared from a mixture of one part cement and three parts sand, by weight, shall, after seven days, develop a tensile strength of not less than 160 pounds per square inch.

Cement mixed neat with about 27 per cent. of water to form a stiff paste, shall, after thirty minutes, be appreciably indented by the end of a wire one-half inch in diameter, loaded to weigh one-quarter pound. Cement made into thin cakes on glass plates shall not crack, scale or warp under the following treatment: Three pats shall be made and allowed to harden in moist air at from 60 to 70 degrees F. One of these shall be subjected to water vapor at 176 degrees F. for three hours, after which it shall be immersed in hot water for forty-eight hours; another shall be placed in water from 60 to 70 degrees F., and the third be left left in moist air.

Natural Cement.—Natural cement shall be of such fineness that not less than 90 per cent. shall pass through a standard brass cloth sieve of 50 meshes per linear inch.

Neat cement briquettes shall have a tensile strength of not less than 120 pounds after remaining one day in air and six days in water and shall gain in strength with age. Briquettes of one part cement and one part sand, by weight, shall at the end of seven days develop a tensile strength of not less than 85 pounds per square inch.

A boiling test will also be made by mixing cakes as above, placing them at once in cold water, raising the temperature of the water to boiling in about an hour, continuing boiling for three hours, and then examining for checking and softening.

The specifications of the Philadelphia & Reading Railway Company for cement are as follows:

All cements purchased by this company must conform to the following requirements:

(1) *Sampling.*—A one-pound sample will be taken from each of five barrels or bags in every carload or fraction thereof. These five portions will be thoroughly mixed and the accept-

ance or rejection of the entire carload will depend upon the results of the examination of this sample.

(2) *Fineness.*—No. 50, 100, and 200 sieves made of brass wire cloth, having approximately 2,400, 10,200, and 35,700 meshes per square inch, respectively, with diameter of wire of .0090, .0045, and .0020 inch, respectively, shall retain not exceeding the following residue:

	Portland Cement.	Natural Cement.
No. 50 sieve	1 per cent	2 per cent
No. 100 "	10 per cent	15 per cent
No. 200 "	30 per cent	35 per cent

(3) *Composition.*—Magnesia (MgO), not exceeding, Portland 5 per cent., Natural 5 per cent. Sulphuric acid (SO_3), not exceeding, Portland 2 per cent., Natural 2½ per cent.

(4) *Specific Gravity.*—Not less than, Portland 3.05, Natural 2.90.

(5) *Time of Setting.*—Neat cement of normal consistency, at temperature between 60 degrees F. and 70 degrees F., shall conform to the following time of setting, as determined by Gilmore's wire test:

	Portland.	Natural.
Initial set, not less than	30 min.	10 min.
Hard set, not less than	....	30 min.

(6) *Constancy of Volume.*—Pats of neat cement of normal consistency, one-half inch thick, with thin edges, immersed in water after hard set, shall show no sign of checking or disintegration.

(7) *Tensile Strength.*—Briquettes of cement one square inch in cross section shall develop the following tensile strength:

	Portland.	Natural.
Neat, 24 hours, (in water after hard set)	175 lbs.	100 lbs.
Neat, 7 days (1 day in air, 6 days in water)	450 lbs.	200 lbs.
Neat, 20 days (1 day in air, 27 days in water)	500 lbs.	300 lbs.
	Portland one part cement and three part sand.	Natural one part cement and two parts sand.
Sand, 7 days (1 day in air, 6 days in water)	170 lbs.	115 lbs.
Sand, 20 days (1 day in air, 27 days in water)	240 lbs.	200 lbs.

(8) *Briquette Making.*—Six ounces of the cement will be quickly and thoroughly kneaded up with water in such proportions that a ball of the mixture taken at once and dropped upon the slab from a height of three feet shall neither flatten materially nor crack. This proportion of water will then be added all at once to another batch of the cement and quickly

worked up until the mass is homogeneous. The paste will then be pressed into standard molds without ramming, and struck off upon both sides with the trowel. Pats of neat cement for determining the time of setting and constancy of volume will be made from the same paste.

(9) *Sand Briquettes.*—Sand and cement to be thoroughly mixed dry, and all the water required to be added at once. The sand used shall consist of crushed quartz which will pass a No. 20 sieve and be retained by a No. 30 sieve. As soon as the briquettes are hard enough to handle they are to be removed from the molds and kept in a damp closet or covered with damp cloths until placed in water. The briquettes to be broken in test machine immediately after removal from water.

(10) *Rejected Cement.*—Cement not in accordance with above specifications, to be returned at expense of shipper, and in case of rejection, sample upon which test is based to be held for one month at the disposal of the shipper.

The specifications of the Chicago & Alton Railway Company for cement are as follows:

Weight.—All cement purchased by the railway company shall be packed in barrels or in sacks, four sacks per barrel for Portland, and two or three sacks per barrel for Natural cement; 380 lbs. net of Portland cement and 265 lbs. net of Natural cement shall be considered a barrel, and all cement accepted shall be paid for on this basis.

Damaged Cement.—Any packages in which the cement has been damaged by moisture before delivery to the company, will be rejected, and, if numerous, the whole carload or boatload may, at the discretion of the chief engineer, be rejected without further test.

Rejected Cement.—All cement rejected by the company, through failure to stand the following tests, or for any other good and sufficient reason, shall be at once removed at the expense of the contractor.

Contract Work.—Cement used on contract work for the company shall be subject to the same requirements and tests as that purchased direct by the company and the contractor will be required to keep on hand a supply of accepted cement, sufficient to keep the work going until more is accepted.

Sampling.—From 5 per cent. to 20 per cent. of the packages will be sampled for testing purposes. These samples may be tested separately, or mixed and then tested, at the discretion of the chief engineer.

Test Requirements.—The cement shall equal the following requirements:

Kind of Cement	Fineness. Per cent. passing sieves.		Tensile Strength. Pounds per square inch. Neat.		1 c. to 1 s. by volume		1 c. to 3 s. by volume		Time of Setting. Initial	Final.
	No. 50	No. 100	7 Da	28 Da	7 Da	28 Da	7 Da	28 Da		
Portland ...	98	93	400	480			150	200	30 minutes to 5 hours.	50 minutes to 10 hours.
Natural......	90	75	100	150	75	110			10 minutes to 2 hours.	20 minutes to 3 hours.

Thin pats or cakes of neat cement allowed to take final set in moist air must withstand indefinite exposure in water or air at any temperature, to which the cement may be exposed in work, without giving any evidence of swelling, checking or warping out of shape, or softening.

Pats of neat Portland cement allowed to take final set in moist air must withstand exposure for six hours in steam at atmospheric pressure above the surface of boiling water, or three hours in steam and three hours in boiling water, without becoming soft or showing any signs of swelling, checking, or warping out of shape. Pieces of briquettes broken in tensile tests of Portland cement, either neat or mortar, must remain hard and sound after the same exposure to steam or boiling water as specified for the pats.

Consistency of Mixing.—The briquettes for tensile tests shall be mixed with sufficient water to render the mortar plastic, so that the moulds can be easily filled by thumb pressure.

The neat pats for setting and soundness test should be mixed somewhat wetter than the briquettes, so that they can be readily finished smooth with thin edges on glass.

The following table gives the amounts of water usually required to accomplish these results:

Kind of Cement	Water Required in Per Cent. by Weight of Total Dry Ingredients, *i. e.* Cement and Sand. For Briquettes. Neat	1 c. to 1 sd.	1 c. to 3 sd.	For Pats. Neat.
Portland..................................	20 to 24		8 to 12	28 to 30
Natural....................................	32 to 36	14 to 18		38 to 42

Explanations and Definitions.—The briquettes for tensile test shall set twenty-four hours in moist air and the remainder of the time in water of 55 degrees to 65 degrees F.

The sieves for fineness test shall be standard No. 50 and No. 100 sieves, *i. e.,* having 50 and 100 meshes per linear inch, respectively.

Initial set shall mean that the pat supports ¼ of a pound on a wire 1-12 inch in diameter, and final set that it supports one pound on a wire 1-24 inch in diameter, without indentation.

In making the mortar briquettes the proportions by volume shall be on the basis of 100 lbs. per cubic foot for the sand, 100 lbs. for the Portland cement, 67 lbs. for the Natural cement.

Sand.—The sand used in making the mortar briquettes shall be clean and shall be screened through a No. 8 sieve, 8 meshes per linear inch, and caught on a No. 50 sieve, 50 meshes per linear inch.

Uniformity of Product.—When a given brand of cement has been tested for some time and found to be fairly uniform in its action under the different tests, a sudden wide variation from this normal action in any kind of test shall be looked upon with suspicion and should lead to more extended and longer time tests.

The chief engineer shall have the right to make any other tests, or use any other means in his power, to gain information as to the quality of cement, and reserves the right to reject any cement which he is not fully satisfied is suitable for the work for which it is intended.

CONCRETE ARCHES.

Three specifications are given for the cement for concrete arch construction to show the variations in requirements in first-class structures. The specifications for the work are given in a subsequent chapter. The first is for a concrete bridge at Pine Road over Pennypack Creek, Philadelphia, built in 1893, Monier construction, and said to be the first concrete arch highway bridge in the United States. It was designed and construction superintended by the Bureau of Highways of Philadelphia. After careful examination of various brands of cement a single brand of German Portland cement was specified and used, without further specification.

The second, for a Melan arch bridge constructed at Topeka, Kansas, in 1896, is as follows: The Portland cement shall be a true Portland cement, made by calcining a proper mixture of calcareous and clayey earths; and the contractor shall fur-

nish one or more certified statements of the chemical composition of the cement and of the raw materials from which it is manufactured. Only one brand of Portland cement shall be used on the work, except with permission of the superintendent, and it shall in no case contain more than 2 per cent. of magnesia in any form. The fineness of the cement shall be such that at least 98 per cent. shall pass through a standard brass cloth sieve of 74 meshes per linear inch, and at least 95 per cent. shall pass through a sieve of 100 meshes per linear inch. Samples for testing may be taken from each and every barrel delivered as superintendent may direct. Tensile tests will be made on specimens prepared and maintained until tested at a temperature of not less than 60 degrees F. Each specimen shall have an area of 1 square inch at the breaking section, and, after being allowed to harden in moist air for twenty-four hours, shall be immersed and retained under water until tested. The sand used in preparing the test specimens shall be clean, sharp, crushed quartz, retained on a sieve of 30 meshes per lineal inch, and shall be furnished by contractor. No more than 23 to 27 per cent. of water by weight shall be used in preparing the test specimens of neat cement and in making the test specimens, 1 of cement to 3 of sand, no more than 11 or 12 per cent. of water shall be used. Specimens prepared from neat cement shall after seven days develop a tensile strength not less than 400 pounds per square inch. Specimens prepared from a mixture of 1 part cement to 3 parts sand (by weight), shall, after seven days, develop a tensile strength of not less than 140 pounds per square inch, and after twenty-eight days not less than 200 pounds per square inch. Specimens prepared from a mixture of 1 part cement and 3 parts sand (by weight), and immersed after twenty-four hours in water to be maintained at 176 degrees F. shall not swell or crack, and shall after seven days develop a tensile strength of not less than 140 pounds per square inch. Cement mixed neat with about 27 per cent. of water to form a stiff paste, shall, after 30 minutes, be appreciably indented by the end of a wire 1-12 inch in diameter, loaded to weigh ¼ pound. Cement made into thin cakes on glass plates shall not crack, scale or warp under the following treatment: Three pats shall be made and allowed to harden in moist air at from 60 degrees to 70 degrees F.; one of these shall be subjected to water vapor at 176 degrees F. for three hours, after which it shall be immersed in hot water for forty-eight hours; another shall be placed in water at from 60 degrees to 70 degrees F., and the third shall be left in moist air. Samples of 1 to 2 mortar and of concrete shall be made and tested from time to time as

directed by the superintendent. All cement shall be housed and kept dry till wanted in the work.

The third specification given is for Melan arch bridges constructed in Indianapolis, in 1900.

All cement used for the arches shall be either (one of four brands of German and Danish cement mentioned). Cement for the other parts of the work shall be such as is satisfactory for cement sidewalks, class "B," standard specifications form Q, and must also conform to the general specifications for cement (form H).

The specifications for class "B" sidewalks is as follows:

For class "B" sidewalks, the following brands of cement shall be allowed: (Fourteen German, Danish and Belgian cements and four American Portland cements are named).

The general specifications for cement (form H) are as follows:

1. Any cement without maker's name and brand on the barrel or package will be rejected without test.

2. All required samples for testing must be furnished by the contractor.

3. A supply of accepted cement must be kept on hand by the contractor.

4. Rejected cement must be removed by the contractor from the work at once.

5. Cement shall be subject to reinspection, test and rejection, if necessary, at any time.

6. All desired information as to place, materials and method of manufacture, and name of makers and agents, shall be furnished whenever desired by the Board of Public Works and City Engineer.

7. Hydraulic cement shall be of the best quality of natural cement, newly manufactured, well housed and preserved dry until required for use. It shall be finely ground, not less than 80 per cent. passing through a sieve of 80 meshes to the linear inch. When tested neat in the usual manner, it must stand a proof tensile strain of 60 pounds per square inch on specimens allowed to set 30 minutes in air and twenty-four (24) hours under water. It shall also stand 100 pounds when allowed to set one day in air and six days in water, and 150 pounds per square inch when allowed to set one day in air and 27 days in water. When mixed one part of cement and two parts of sand, by weight, it shall stand 30 pounds when allowed to set one day in air and 27 days in water. Cakes one-half inch in thickness, with thin edge, shall show no cracks or softness after

seven days in water. Certificates of inspection at the mills that the cement fulfills these requirements may be required by the Board of Public Works, the cost of said inspection to be paid by the contractor.

8. Portland cement for concrete, plastering catch-basins and other miscellaneous purposes, shall be equal to the best quality of Portland cement made from selected rock, carefully manufactured, which has been well seasoned and housed and kept dry until required for use. It shall be finely ground, not less than 90 per cent. passing through a sieve of 80 meshes to the lineal inch. Neat cement shall not set in less than one hour unless quick setting is specifically called for, when it shall not set in less than 10 minutes. When tested in the usual manner it must stand a proof tensile strain of 125 pounds per square inch when allowed to set in air until hard, and the remainder of 24 hours in water. It shall also stand 350 pounds when allowed to set one day in air and six days in water, and 500 pounds when allowed to set one day in air and 27 days in water. When one part of cement is mixed with three parts of sand, by weight, it shall stand 100 pounds per square inch when allowed to set one day in air and six days in water, and 200 pounds when allowed to set one day in air and 27 days in water. Cakes one-half inch in thickness, with thin edges, shall show no cracks, blowing or softness after seven days in water.

9. Portland cement for sidewalks and other work requiring special qualities shall be equal to the best quality of German Portland cement, made from an artificial mixture of proper materials and according to the best methods of mixing, burning and grinding. It must be well seasoned and have been thoroughly well protected from injury by moisture and otherwise. It shall be finely ground, not less than 95 per cent. passing through a sieve of 80 meshes to the lineal inch, and 90 per cent. through a sieve of 100 meshes to the lineal inch. When tested neat in the usual manner, it must stand a proof tensile strain of 475 pounds per square inch when allowed to set one day in air and six days in water, and 550 pounds when allowed to set one day in air and 27 days in water. When mixed one part of cement with three parts of sand, by weight, it shall stand 150 pounds when allowed to set one day in air and six in water, and 250 pounds when allowed to set one day in air and 27 in water. Cakes of cement left 24 hours in boiling water shall show no signs of cracks, blowing or softness. Any brand of Portland cement which at any time appears inferior or shows a backward tendency, signs of deterioration or blowing, will be at once rejected, no matter how good previous tests may have been, and any work done with such cement must be at

once removed and replaced as the engineer may direct, and without extra allowance to the contractor therefor. Uniformity in quality is essential in this grade of cement, and any cement which fails to give uniform results under uniform and approved treatment will be rejected even if it complies with the specifications in other respects. Evidence of the actual conduct of cement in sidewalks will also be required in case of cements not now in use in the city.

10. Brands of Portland cement which have been tested in the laboratory and are satisfactory for sidewalk construction are more specifically mentioned under specifications for "Cement Sidewalks, Form Q." The brands of cement specified under "Cement Sidewalks, Form Q," as may be tested and found to comply with these specifications, can be used provided the following conditions are fulfilled:

First. All cement shall be shipped here in barrels.

Second. The cement companies shall send with every shipment of cement a sworn statement, showing the length of time the cement has been stored, the result of seven-day, twenty-eight-day, and fifty-six-day tests, using one part of cement to three parts of sand, by weight, in making briquettes. Cement from one barrel out of each lot of ten barrels of a shipment shall be tested. The test shall be made by a firm of cement testers, satisfactory to the City Civil Engineer, and each barrel of a shipment shall be stamped with the initials of the cement tester, the date when cement was tested, and the number of the barrel.

Third. A chemical analysis of the cement shall be made by a chemist, satisfactory to the Board of Public Works and the City Civil Engineer; all expense of said analysis shall be borne by the cement company furnishing the cement, or its agent.

The increase in the requirements made of cement since 1900 is shown by comparing the above specifications with the following adopted for use in Indianapolis in January, 1904:

1. *Inspection.*—All cements shall be inspected, and those rejected shall be immediately removed from the work by the contractor.

2. *Storage.*—On all main sewers, bridges (unless otherwise ordered) and such branch sewers or other work as the City Civil Engineer may designate, and shall be provided a suitable house for storing the cement.

3. *Protection.*—Accepted cement, if not used immediately, must be thoroughly protected from the weather, and never placed on the ground without proper blockings, and may be re-inspected at any time.

4. *Failure.*—The failure of a shipment of cement on any

work to meet these requirements may prohibit further use of the same brand on that work.

The acceptance of a cement to be used shall rest with the Board of Public Works and the City Civil Engineer, and will be based on the following requirements:

NATURAL CEMENT.—By natural cement is meant one made by calcining natural rock at a heat below incipient fusion and grinding the product to powder.

Weight.—Each bag of natural hydraulic cement must contain 150 lbs. net; each barrel 300 lbs. net.

5. *Specific Gravity and Fineness.*—The cement shall have a specific gravity of not less than 2.9.

Ninety-five (95) per cent. by weight must pass through a sieve made of No. 35 wire, Stubbs gauge, 2,500 openings to the square inch.

Eighty (80) per cent. by weight must pass through a sieve made of No. 40 wire, Stubbs gauge, 10,000 openings to the square inch.

6. *Constancy of Volume.*—Round pats of neat cement, about three (3) inches in diameter, one-half (½) inch thick at the center and tapering to a feather's edge, mixed in the same manner as the neat cement briquettes on a glass plate, shall not show any signs of warping or cracking after twenty-eight (28) days in either air or water.

7. *Time of Setting.*—The cement shall get its initial set in not less than thirty (30) minutes. This being determined by means of the Vicat needle, from pastes of neat cement of normal consistency, the temperature being between 60 and 70 degrees F.

8. *Tensile Strength.*—Briquettes, one (1) square inch in cross section, shall develop the following ultimate tensile strength:

Ages.	*Strength.*
24 hours (in water after hard set)	90 pounds
7 days (1 in air, 6 in water)	150 pounds
28 days (1 day in air, 27 in water)	250 pounds
7 days (1 day in air, 6 in water), 1 cement, 2 standard sand	120 pounds
28 days (1 day in air, 27 in water), 1 cement, 2 standard sand	175 pounds

PORTLAND CEMENT.—The cement shall be a true Portland cement, made by calcining a proper mixture of calcareous and clayey earths, and if desired a certified statement shall be furnished of the chemical composition of the cement, and the raw materials from which it is manufactured. It shall be free from lumps, dry and finely ground.

Weight.—Each barrel must at least weigh 400 pounds gross and be properly lined so as to be effectually sealed from dampness.

Specific Gravity and Fineness.—The cement shall have specific gravity of not less than 3.1.

Ninety-eight (98) per cent. by weight must pass through a sieve made of No. 35 wire, Stubbs gauge, 2,500 openings to the square inch.

Ninety per cent. by weight must pass through a sieve made of No. 40 wire, Stubbs gauge, 10,000 openings to the square inch.

Constancy of Volume.—Round pats of neat cement about three inches in diameter, one-half inch thick at the center and tapering to a feather's edge, mixed in the same manner as the neat cement briquettes and placed on a glass plate, shall not show any signs of warping or cracking after twenty-eight days in air or water, or when placed six hours in boiling water.

Time of Set.—The cement shall get its initial set in not less than thirty minutes, and its final set in not less than fifty minutes nor more than ten hours. The test being made in the same way as for the natural cement.

Tensile Strength.—Briquettes one square inch in cross section shall develop the following ultimate tensile strength.

Ages.	*Strength.*
24 hours (in air)	100 pounds
7 days (1 in air, 6 in water)	400 pounds
28 days (1 in air, 27 in water)	575 pounds
7 days (1 in air, 6 in water), 1 of cement, 3 of standard sand	120 pounds
28 days (1 in air, 27 in water), 1 of cement, 3 of standard sand	200 pounds

Sulphuric Acid and Magnesia.—It shall contain not more than one and three-quarters per cent. of anhydrous sulphuric acid (SO_3) nor more than 3.5 per cent. of magnesia.

PUZZOLAN.—By puzzolan cement is meant one made by grinding together without subsequent calcination granulated blast furnace slag with slaked lime.

Weight.—The average weight per barrel shall not be less than 330 pounds net, four sacks shall contain one barrel of cement.

Specific Gravity and Fineness.—The cement shall have a specific gravity not less than 2.7.

Ninety-seven per cent. by weight must pass through a sieve made of No. 40 wire, Stubbs gauge, having 10,000 openings to the square inch.

Constancy of Volume.—Round pats of neat cement about three inches in diameter, one inch thick at the center and tapering to a feather's edge, mixed in the same manner as the neat

cement briquettes, and placed on a glass plate, shall not show any signs of warping or cracking after 28 days in water.

Time of Setting.—The cement shall not acquire its initial set in less than 45 minutes, and shall acquire its final set in 10 hours. The test made in same way as for natural cement.

Tensile Strength.—Briquettes one square inch in cross section shall develop the following tensile strength:

Ages.	*Strength.*
7 days (1 in air, 6 in water)	350 pounds
28 days (1 in air, 27 in water)	500 pounds
7 days (1 in air, 6 in water), 1 cement, 3 standard sand	130 pounds
28 days (1 in air, 27 in water), 1 cement, 3 standard sand	220 pounds

If a sample of cement submitted for test shows higher test than those given above, the average of tests on subsequent shipments must come up to those found with the sample.

Brands of Portland cement which have been tested in the laboratory of the City Civil Engineer and found to comply with these specifications can be used, provided the following conditions are fulfilled:

First. All cement shall be shipped in strong paper bags or barrels.

Second. With each shipment of cement a certificate of tests made at the mill and the time that the cement has been stored shall be submitted.

Third. Contractors must submit the cement and afford every facility for inspection and testing at least fourteen (14) days before desiring to use it. The engineer in charge of the testing laboratory shall be notified at once on the receipt of the shipment of cement.

Fourth. Any cement without the stamp of the engineer in charge of the laboratory, the maker's name, and the brand on the barrel or package, will be rejected without test.

Additional Requirements.—Should there be discovered at any time, any characteristics in any cement furnished for the work that would be objectionable in that work, the further use of cement of the same brand on all work of that class will be prohibited regardless of the fact that it has successfully withstood the tests hereinbefore specified.

All cement shall meet such additional requirements as to the "chemical tests" as the City Civil Engineer may determine. The requirements for set may be modified where the conditions are such as to make it advisable.

CEMENT SPECIFICATIONS FOR BRIDGE AT HARTFORD, CONN.

The following specifications and method of sampling were

adopted by Edwin D. Graves for a bridge at Hartford, Conn., erected by the Connecticut River Bridge and Highway District Commission in 1904, in which about 100,000 barrels of Portland cement were used:

All cement shall be pure American Portland. All cement shall be dry and free from lumps, well seasoned and free from slag or other waste products, such as ground limestone or sand. Manufacturers must guarantee that all cement has been seasoned or subjected to aeration at least thirty days before leaving the works. Only high grade American Portland cements of established reputation, which have been made by the same mill and process and used successfully under similar conditions to to those of the proposed work, will be considered, and the decision of the engineer shall be final. The contractor shall furnish the engineer with all the information which he may require in regard to the record or history of the cement which he proposes to use. It is desirable that no change in the brand or quality of cement be made throughout the work, and considerable preference will be given to that cement whose makers can guarantee to supply regularly and on time the entire quantity required.

Tests, in general, are to be in accordance with the rules of the American Society of Civil Engineers, except where otherwise noted or required by the engineer.

All cement is to be furnished either in first-class barrels or duck bags, and each package must be perfect, and have the name of the manufacturer clearly marked upon it.

The contractor must keep on hand in the storehouse at the work a sufficient supply, in the original packages, to allow a thirty day test of each lot or consignment of cement before any of it will be allowed to be used in the work. The cement must be stored in tiers in a suitable dry storehouse, at least one foot above the ground, so that every bag or barrel is accessible for sampling and marking. Each lot or consignment received must be piled by itself and its date of receipt plainly indicated. In general, samples shall be drawn from one barrel in 25 or one bag in 100, but the engineer reserves the right to sample any or all packages received, and to order a retest at any time.

No cement can be used in the work until it has been accepted by the engineer, and each package, after acceptance, must bear an acceptance tag or label, to be affixed by the engineer to each lot which has satisfactorily passed all the tests which he desires.

Any cement which has been rejected shall be immediately removed from the storehouse and from the vicinity of the work.

As the accepted cement is removed from the storehouse for use in the work, the tags or labels must be removed or destroyed by the engineer.

Each barrel of cement must weigh at least 375 pounds net, and will be figured as four cubic feet of cement, loose measure. Each bag is figured to contain one fourth of a barrel, both in weight and measure.

The proportion of lime to silica shall be about three to one. Sulphuric acid, less than 1.75 per cent. Magnesia, less than 3 per cent.

Fineness shall be tested by sieves of best standard make: No. 100 sieve, 10,000 meshes per square inch. No. 200 sieve, 40,000 meshes per square inch. Ninety-five per cent., by weight must pass a No. 200 sieve. The specific gravity shall be between 3.10 and 3.20. Initial set not less than one hour. Final set not over eight hours.

Two cakes of neat cement shall be molded on glass and be made about 3½ inches in diameter, ⅜-inch thick at the center, drawn down to a sharp edge at the circumference. One cake shall be immersed in cold water, after having set hard, and then examined from day to day for a period of seven days, in order to detect surface cracking and warping. The other cake, after having set hard, shall be immersed in water at 70 degrees F., supported on a rack above the bottom of the receptacle and the water gradually raised to the boiling point and maintained at this temperature for 24 hours. Examination of the cake at the end of that time must show no signs of checking, cracking or distorting. The surface color of these cakes, when left in the air until they are set hard, and after immersion in both hot and cold water, must be uniform throughout, of a bluish-gray, and free from light yellowish blotches.

Should the sample fail to pass the hot water test, the engineer reserves the right to reject the lot or to order a retest, or to subject the sample to chemical analysis in order to determine whether said failure to pass the hot water test was occasioned by free lime or other deleterious conditions. The engineer may withhold his approval until the result of the twenty-eight day test of the cake in cold water can be observed, or he may order a new boiling test from new samples drawn from the same lot but from different packages. If the twenty-eight day cold water test or the second boiling test is unsatisfactory, the lot must be rejected.

Neat briquettes must stand a minimum tensile strain per square inch: 24 hours in air, 200 pounds; 24 hours in air and 6 days in water, 500 pounds; 24 hours in air and 27 days in water, 650 pounds.

Sand mortar briquettes, three parts sand (standard crushed quartz) to one part neat cement, must stand a minimum tensile strain per square inch without breaking: 1 day in air and 6 days in water, 175 pounds; 1 day in air and 27 days in water, 275 pounds.

The standard quartz sand shall pass a standard sieve of 20 meshes per lineal inch, 400 meshes per square inch, and be all retained upon a standard sieve with 30 meshes per lineal inch or 900 meshes per square inch.

The tensile strength of both neat and sand briquettes shall show a satisfactory increase of strength up to periods of one year. The contractor shall, if required, furnish previously obtained evidences of the strength of the cement at periods of three, six, nine and twelve months.

When making briquettes, well dried cement and sand will be used. Neat cement will be mixed with 20 per cent. of water by weight; three to one sand and cement mixture, with 12½ per cent. of water by weight.

Sampling is thoroughly and systematically done, and one of the most notable features of this division of the work lies in the way in which the samples are used. On the arrival of a car containing 600 bags or thereabouts, a sample is taken from every 100 bags as they are being taken to the storehouse, and these are mixed to form the sample by which that car will be judged for acceptance or rejection. The tests made on this sample are embodied in what is called the "acceptance" cement report, and they include the fineness, soundness, setting time, tensile strength neat and sand seven days and twenty-eight days. Four such car samples are subsequently taken and mixed to furnish the data for the "mixed sample" cement report, in which the features already determined are entered by their average, and in addition briquettes are made so that data will be furnished for the three months, six months, and one year reports. It is believed that the chief engineer has by this method the fullest knowledge of the character of the cement which is offered to him, and of that which has gone into his work that it is possible to have of it, and at a very reasonable cost. Five-inch concrete cubes are also made from the mixer, and these are laid away for testing at long periods. Mr. Graves discovered that he secures better results by making a prism of such concrete several feet long and having the cubes sawed out of it by the marble cutter.

A modification of the procedure of sampling has later been introduced to further facilitate the direct transmission of the cement to the concrete mixer without passing through the storehouse, and this may be adopted for all of the open season. It

consists in sampling certain bins at the cement mill by means of numerous samples, and locking and sealing these bins until the samples have been through the regular series of tests at the laboratory at the bridge site. Cars are loaded only from the accepted bins, and the cement is sent forward for transshipment at Jersey City, where another representative of the laboratory certifies to the proper transshipment and sends forward to the Hartford office all information about the particular lot of cement on the barge. Complicated as this may seem, the system and conditions are such that the engineer of this great work can congratulate himself on having cement inspected at a cost which is very reasonable.

CEMENT IN SEA WATER.

The following specification for cement used in sea-water is taken from those for Wallabout Improvement, Brooklyn, N. Y.:

All the cement to be furnished under this contract must be of the class of such material known as high-grade Portland cement, free from lumps, dry and finely ground, and *unless as otherwise specified* must be of one or more of the following brands (three German brands named). Cement of other brands may be furnished provided the contractor submits proof satisfactory to the engineer that it has been used in making large masses of concrete, which have been exposed to the action of sea-water for at least two years previous to the date of this contract, and that such concrete now shows no signs of deterioration which might be imputed to defective qualities in the cement.

All the cement shall be composed of lime, silica and alumina in their proper forms and proportions, be as free as possible from all other substances and contain no adulterant in injurious proportions. The ratio of the weight of silica and alumina to the weight of the lime in the cement shall not be less than 45 to 100. The cement shall not contain more than 3 per cent. of magnesia nor more than 1 per cent. of sulphuric acid.

The cement shall not have a lower specific gravity than 3.10.

All the cement shall be of a fineness so that 99 per cent. by weight shall pass through a No. 50 sieve of No. 35 wire; 90 per cent. shall pass through a No. 100 sieve of No. 40 wire; and 70 per cent. shall pass through a No. 200 sieve of No. 45 wire, Stubbs' gauge.

The cement must not take its initial set in less than 30 minutes after mixing. It shall take its hard set in not less than 3 hours, and in not more than 8 hours.

The cement will be said to have attained its initial and its

hard set when it bears without indentation, respectively, a wire 1-12 inch in diameter loaded to weigh 1-4 pound, and a wire of 1-24 inch in diameter loaded to weigh 1 pound, it having been previously mixed neat with about 25 per cent. of its weight of water and worked for from 1 to 3 minutes into a stiff plastic paste.

All the cement shall be capable of developing a tensile strength under various conditions as follows:

	Age.	Tensile Strength
Mixed neat with about 25 per cent. of water by weight and worked to stiff plastic paste.	24 hours, in water after hard set	150
	7 days, 1 in air 6 in water 60°	400
	28 days, 1 in air 27 in water 70°	600
Mixed with 3 parts sand by weight and 12 per cent. water to stiff plastic paste.	7 days, 1 in air 6 in water 70°	150
	28 days, 1 in air 27 in water 70°	240

To determine the tensile strength four briquettes of the cement under each of the above conditions will be broken in a Riehle or Fairbanks or other testing machine satisfactory to the engineer.

The sand to be used in making briquettes will be clean, dry, crushed quartz, trap-rock or granite, passing a No. 20 sieve of No. 28 wire and caught on a No. 40 sieve of No. 31 wire, Stubbs' gauge. The briquettes will be of the form recommended by the American Society of Civil Engineers.

All cement must be sound in every respect and show no indications of distortion, change of volume or blowing when subjected in the form of pats to exposure in air and fresh and sea water of temperature from 60 degrees to 212 degrees, as follows: The pats will be made of neat, unsifted cement, mixed with fresh water to the same consistency as before stated for briquettes, and will be about 3 inches in diameter, having a thickness at the center of about ½ inch, tapering to about ⅜ inch at the edges. They will be moulded on plates of glass and kept thereon during examination. (a) One or more of these pats will, when set hard, be placed in fresh water of temperature between 60 degrees and 70 degrees for from 1 to 28 days. (b) One or more of these pats will be allowed to set in moist air at a temperature of about 200 degrees for about 3 hours. It will then be placed and kept in boiling water for a period of from 6 to 24 hours. (c) One or more of these pats will be allowed to set in moist air at a temperature of about 100 degrees for 3 hours; it will then be placed and kept in water of temperature of 110 degrees to 115 degrees for a period of from

24 to 48 hours. (d) One or more of these pats may be subjected to any or all of the above indicated tests (a, b and c), using sea water instead of fresh water. (e) One pat will be kept in the air for 28 days and its color observed, which shall be uniform throughout, of a bluish gray, and free from yellow blotches. A failure to pass test (b) will not necessarily cause the rejection of the cement, provided it passes the other tests for soundness as noted in (a, c, d and e) and is satisfactory in other respects to the engineers.

All the above tests may be modified and other tests in addition thereto or in substitution therefor required at the discretion of the engineer to practically determine the fitness of the cement for its intended use.

The contractor pays the cost of tests of cement which are to be made by the engineer of the work or by one or more of three testing laboratories mentioned.

As many tests as desired by the engineer must be made for composition and specific gravity and one sample shall be tested for each 100 barrels for fineness, set, tensile strength and soundness.

All the cement must be furnished in the original package in strong, substantial barrels, which shall be plainly marked with the brand or mark of the maker of the cement. Each barrel must be properly lined with paper or other material so as to effectually protect the cement from dampness. Anycement damaged by water to such an extent that the damage can be ascertained from the outside will be rejected in toto and the barrels unopened. Barrels containing a large proportion of lumps will also be rejected. Broken barrels of cement, if otherwise satisfactory, will be counted as half-barrels.

The engineer makes the tests upon such proportions of the whole amount of cement as he sees fit and his decision is final. He can refuse to accept cement without test and without giving his reasons.

MUNICIPAL PUBLIC WORKS.

There are one or two interesting points in the following from the specifications for the Pennsylvania Avenue Subway, Philadelphia.

All the brick work of the sewers except that in the well-holes was laid in natural hydraulic cement mortar. In the well-holes Portland cement was specified. In all cases the proportions were 1 of cement to 2 of sand. All concrete used was composed of 1 part natural hydraulic cement, 2 parts sand and 4 parts of stone or furnace slag.

Briquettes 1 square inch in section made from the natural

hydraulic cement mortar in the mixing box on the work were required to develop tensile strength of 40 pounds after 1 day in air and 6 days in water. Portland cement mortar under like conditions must show 150 pounds tensile strength.

The other requirements of natural hydraulic cement were as follows: Weight shall not be less than 112 pounds per imperial bushel; residue on No. 50 sieve not over 4 per cent. by weight, on a No. 100 sieve 25 per cent., on a No. 200 sieve 50 per cent. Pats of cement ½ inch thick, 60 degrees to 70 degrees F., shall develop initial set in not less than 10 minutes and hard set in not less than 30 minutes, the amount of water being just sufficient to form a stiff plastic paste. The tensile strength required was 75 pounds in 24 hours, in water after hard set; 150 pounds, 1 day in air and 6 days in water; 250 pounds, 1 day in air and 27 days in water. Mortar of 1 cement to 1 of standard quartz sand must show 75 pounds tensile strength in 7 days.

For municipal work the city of Philadelphia has the strongest specifications for cement. The city has a complete testing laboratory under the Bureau of Surveys, Department of Public Works, and a complete organization for keeping close watch of the materials in use, and can do so at comparatively slight expense.

1. *Inspection.*—All cements shall be inspected, and those rejected shall be immediately removed by the contractor. The contractor must submit the cement, and afford every facility for inspection and testing, at least twelve (12) days before desiring to use it. The engineer in charge of testing laboratory shall be notified at once upon the receipt of each shipment of cement on the work.

2. *Packages.*—No cement will be inspected or allowed to be used unless delivered in suitable packages properly branded.

3. *Storage.*—On all main sewers, bridges (unless otherwise ordered), and such branch sewers or other work as the chief engineer may designate, shall be provided a suitable house for storing the cement.

4. *Protection.*—Accepted cement, if not used immediately, must be thoroughly protected from the weather, and never placed on the ground without proper blockings, and may be re-inspected at any time.

5. *Failure.*—The failure of a shipment of cement on any work to meet these requirements may prohibit further use of the same brand on that work.

The acceptance of a cement to be used shall rest with the chief engineer, and will be based on the following requirements:

Natural Cement.

6. *Specific Gravity and Fineness.*—Natural cement shall have a specific gravity of not less than 2.9, and shall leave, by weight, a residue of not more than two (2) per cent. on a No. 50 sieve, fifteen (15) per cent. on a No. 100 sieve, and thirty (30) per cent. on a No. 200 sieve. The sieves being of brass wire cloth, having approximately 2,400, 10,200 and 35,700 meshes per square inch; the diameter of the wire being .0090, .0045 and .0020 of an inch, respectively.

7. *Constancy of Volume.*—Pats of neat cement one-half (½) inch thick with thin edges, immersed in water after "hard" set shall show no signs of "checking" or disintegration. Similar pats in air shall show no signs of blotching, checking, or disintegration.

8. *Time of Setting.*—It shall develop "initial" set in not less than ten (10) minutes, or "hard" set in less than thirty (30) minutes. This being determined by means of the Vicat needle from pastes of neat cement of normal consistency, the temperature being between 60 degrees and 70 degrees F.

9. *Tensile Strength.*—Briquettes, one (1) square inch in cross section, shall develop the following ultimate tensile strengths:

Age.		Strength.
24 hours	(in water after "hard" set)	100 lbs.
7 days	(1 day in air, 6 days in water)	200 lbs.
28 days	(1 day in air, 27 days in water)	300 lbs.
7 days	(1 day in air, 6 days in water) 1 part of cement to 2 parts of standard quartz sand	120 lbs.
28 days	(1 day in air, 27 days in water) 1 part of cement to 2 parts of standard quartz sand	200 lbs.

Portland Cement.

10. *Specific Gravity and Fineness.*—Portland cement shall have a specific gravity of not less than 3.1, and shall leave, by weight, a residue of not more than one (1) per cent. on a No. 50 sieve, ten (10) per cent. on a No. 100 sieve, and twenty-five (25) per cent. on a No. 200 sieve. The sieves being the same as previously described.

11. *Constancy of Volume.*—Pats of neat cement one-half (½) inch thick with thin edges, immersed in water after "hard" set shall show no signs of "checking" or disintegration. Similar pats in air shall show no signs of blotching, checking or disintegration.

12. *Time of Setting.*—It shall require at least twenty (20) minutes to develop "initial" set under the same conditions as specified for natural cement.

13. *Tensile Strength.*—Briquettes of cement one (1) inch square in cross section, shall develop the following ultimate tensile strengths:

Age.		Strength.
24 hours	(in water after "hard" set)	175 lbs.
7 days	(1 day in air, 6 days in water)	500 lbs.
28 days	(1 day in air, 27 days in water)	600 lbs.
7 days	(1 day in air, 6 days in water) 1 part of cement to 3 parts of standard quartz sand	170 lbs.
28 days	(1 day in air, 27 days in water) 1 part of cement to 3 parts of standard quartz sand	240 lbs.

14. *Sulphuric Acid.*—It shall not contain more than one and three-quarters (1¾) per cent. of anhydrous sulphuric acid (SO_3).

15. *Additional Requirements.*—All cements shall meet such additional requirements as to "hot water," "set," and "chemical," tests, as the chief engineer may determine. The requirements for "set" may be modified where the conditions are such as to make it advisable.

The specifications for cement of the Department of Public Works, Buffalo, N. Y., vary somewhat from those at Philadelphia. Referring to the paragraphs in the Philadelphia specifications the differences are as follows:

Paragraphs 1 to 5 omitted.

6. Fineness of natural cement 85 per cent. on No. 50 sieve.

7. Cement shall be without free lime, and pats made of neat cement shall show no cracking when immersed in water immediately after set and left for 7 days, nor when subjected to hot test for 24 hours.

8. Initial set in not less than 10 minutes, Gillmore needles.

9. Tensile strength: Neat, 1 day, 60 pounds; 7 days, 100 pounds; cement 1, sand 2, 7 days, 30 pounds; 28 days, 70 pounds.

10. Fineness of Portland cement 90 per cent. on No. 100 sieve.

11. Same as 7 above.

12. Initial set of Portland cement in not less than 30 minutes; final set in not less than 3 hours nor more than 8 hours.

13. Tensile strength: Neat, 1 day, 125 pounds; 7 days, 300 pounds; cement 1, sand 3, 7 days, 90 pounds; 28 days, 150 pounds.

14. Sulphuric acid requirements omitted. Portland cement shall not contain more than 3 per cent. by weight of magnesia.

15. Tests shall be made as directed by the engineer in general accordance with the American Society of Civil Engineers standards.

The following differences from the Philadelphia specifications are noted in the specifications of the City Engineer's office, Baltimore, Md.:

Paragraphs 1, 3, 4 and 5 are omitted.

6. Ninety-five per cent. of natural cement must pass a No. 50 sieve.

7. Cakes or pats of neat cement must show no indication of cracking, checking or warping, when exposed in air and water at normal temperature.

9. Tensile strength: Natural cement, 1 day, 75 pounds; 7 days, 150 pounds; 28 days, 225 pounds; 1 cement, 2 sand, 7 days, 80 pounds; 28 days, 140 pounds.

10. Ninety-eight per cent. of Portland cement must pass a No. 50 sieve.

11. Same as 7 above.

12. Initial set shall not develop in less than 30 minutes in slow-setting, and 10 minutes in quick-setting Portland cement.

13. Tensile strength: Portland cement, neat, 1 day, 125 pounds; 7 days, 400 pounds; 28 days, 500 pounds; 1 cement, 3 sand, 7 days, 125 pounds; 28 days, 200 pounds.

14. Omitted.

15. Each bag of natural hydraulic cement must contain 150 pounds net; each barrel 300 pounds. Each barrel of Portland cement must weigh 400 pounds gross, and be properly lined so as to be effectually sealed from dampness.

The specifications in use by the Bureau of Engineering, Pittsburg, Pa., were revised in 1901, and the following is their present form:

All cement required on the work shall be delivered at a warehouse within the limits of the city, and the director notified of each delivery, at least two weeks before it will be needed in the work.

Cement shall be so stored, in a dry place thoroughly protected from rain and dampness, that each shipment is piled to itself and at all times readily accessible for inspection and tests.

Cement will be accepted from reliable manufacturers of well-established reputation only, and the cement will not be tested or permitted to be used unless delivered in original packages properly labeled.

Tests of the cement will, unless otherwise specified, be made at a temperature of from 60 to 70 degrees Fahrenheit.

Samples for test may be taken from every package in each shipment of cement, and unless they meet the requirements herein specified, the whole shipment from which the samples were taken will be rejected.

The sieves used for testing cement for fineness and for gauging the sand to be used in making briquettes for sand tests shall be as follows:

No. 20 sieve shall have 400 meshes to the square inch, and shall be made of wire cloth, No. 28 wire Stubbs' wire gauge.

No. 30 sieve shall have 900 meshes to the square inch and shall be made of wire cloth, No. 31 wire Stubbs' gauge.

No. 50 sieve shall have 2,500 meshes to the square inch and shall be made of wire cloth, No. 35 wire Stubbs' gauge.

No. 100 sieve shall have 10,000 meshes to the square inch, and shall be made of wire cloth, No. 40 wire Stubbs' gauge.

Briquettes for testing strength of cement will be made both of neat cement and sand in the proportions hereinafter specified, with only enough water added to thoroughly moisten the mixture and make it coherent.

After being thoroughly mixed on glass plate the mortar shall be firmly pressed into the molds by hand, and the briquettes so formed placed upon a glass plate and kept there until put in water.

The sand used in preparing briquettes shall be, unless otherwise specified, clean, sharp, crushed quartz, crushed so that the whole of it will pass through a No. 20 sieve and be retained on a No. 30 sieve.

Round pats of neat cement, about three (3) inches in diameter, one-half an inch thick at the center and tapering to a feather's edge, mixed in the same manner as the neat cement briquettes and placed on a glass plate, shall not show any signs of warping or cracking after twenty-eight (28) days in either air or water.

Any cement which shows signs of swelling, after being mixed, will be rejected.

Portland cement shall be ground to such a degree of fineness that not less than 98 per cent. by weight shall pass a No. 50 sieve, and not less than 90 per cent. by weight pass a No. 100 sieve.

Natural cement shall be ground to such degree of fineness that not less than 88 per cent. by weight will pass a No. 50 sieve, and not less than 77 per cent. by weight pass a No. 100 sieve.

The tensile strength of cement will be determined from an average of not less than five briquettes, made of samples taken from the same shipment of cement.

The average ultimate tensile strength of briquettes made of neat Portland cement shall be, after being kept in air one day and in water six days, not less than 400 pounds, and after being kept in air one day and in water 27 days, not less than 550 pounds.

The average ultimate tensile strength of briquettes made of one part by weight of Portland cement and three parts of sand

shall be, after being kept in air one day and in water six days, not less than 120 pounds, and after being kept in air one day and in water 27 days, not less than 175 pounds.

The average ultimate tensile strength of briquettes made of neat natural cement shall be, after being kept in air one day and in water six days, not less than 110 pounds, and after being kept in air one day and in water 27 days, not less than 180 pounds.

The average ultimate tensile strength of briquettes made of one part by weight of Portland cement and three parts of sand shall be, after being kept in air one day and in water six days, not less than 40 pounds, and after being kept in air one day and in water 27 days, not less than 175 pounds.

In addition to the tests above specified, all cement furnished for the work shall be subject to such other tests as may be necessary to determine whether the cement possesses the proper qualities for the particular work for which it is designated.

Should there be discovered at any time, any characteristics in any cement furnished for the work that would be objectionable in that work, the further use of cement of the same brand on all work of that class will be prohibited, regardless of the fact that it has successfully withstood the tests hereinbefore specified.

The above specifications have been changed from those used the previous year as follows: Neat Portland cement tensile strength raised from 375 pounds at seven days and from 510 at 28 days; 3 to 1 sand and Portland cement lowered from 190 pounds at 28 days; neat natural hydraulic cement, 24-hour test omitted; 2 to 1 sand and natural hydraulic cement lowered from 50 pounds at 7 days.

The city of Detroit does not require so much and may secure cement under its specifications which, while passing the tests required, is deficient in a marked degree in other respects. The specifications in use are as follows:

Cement to be put up in cloth or paper sacks, original packages, each sack to be branded with the name of the manufacturer or manufacturers, and to contain 95 pounds net of Portland cement, or 132½ pounds net of natural cement, and to be delivered in such quantities and at such times as the Board of Public Works may direct, unloaded in a warehouse which shall be located on the railroad, between 12th and Riopelle streets, south of Michigan avenue, or Gratiot avenue, in the city of Detroit, and no extra charge shall be made for storage or delivery.

A man satisfactory to the Board of Public Works shall be furnished by the contractor to assist in loading.

The sacks to be the property of the city of Detroit, and each bidder shall state in connection with his bid, the price per cloth sack he will pay for each empty sack delivered at the warehouse aforesaid.

The Board of Public Works reserves the right to reject any cement considered by said Board not equal in quality to the standard above mentioned.

Portland Cement shall be of American manufacture, and shall stand a test of 130 pounds per square inch tensile strain, when made into briquettes and exposed in air until final set and the balance of 24 hours immersed in water. One day in air and 6 days in water shall show a tensile strength of 380 pounds; 1 day in air and 27 in water shall show a tensile weight of one of cement to two of sand, in 7 days it shall stand a tensile strain of 146 pounds, and in 28 days a strain of 216 strength of 520 pounds, and when mixed in proportion by pounds.

In fineness, 95 per cent. shall pass through a No. 50 sieve.

Natural Cement shall be of American manufacture, and shall stand a test of sixty (60) pounds per square inch tensile strain when made into briquettes, exposed 1 hour in air and immersed for twenty-three (23) hours in water; and when mixed in proportions by weight of 1 of cement to 2 of sand, and exposed 1 day in air and 6 days in water, it shall stand a tensile strain of at least fifty (50) pounds per square inch; and in fineness not less than 90 per cent. must pass through a sieve of twenty-five hundred (2,500) meshes to the square inch.

INSUFFICIENT SPECIFICATIONS.

The following cement specifications for 1901, from a city of 90,000 inhabitants, are presented as an unsatisfactory set, which will permit the use of poor cement of both kinds unless arbitrary rejections are made outside of the specifications.

Cement shall be of the best quality of Louisville cement or of cement equal in all respects thereto, fine ground, quick setting, capable when made into testing blocks of withstanding a tension of 60 pounds per square inch of section, when mixed pure and exposed in air 1 hour and 23 hours in water.

The contractor must furnish the cement in strong, perfect paper sacks to any part of the works, and in such quantities as the Commissioner of Public Works may direct, and only upon the written order of said Commissioner. Bids to specify the price per hundred pounds at which the cement is to be furnished. To be weighed on the public scales.

The cement used for the curbing and tiling shall be of the best quality of American or imported Portland cement, capable of withstanding a tensile strength of 500 pounds to the square inch when mixed neat and allowed to stand 1 day in air and 6 days in water.

FOR SEWERS.

For sewer work the following are given as examples of practice:

The Department of Sewers, Reading, Pa., requires:

Composition.—Magnesia not over 2½ per cent.; sulphuric acid not over 2 per cent.

Fineness.—Ninety-five per cent. through a No. 100 sieve; 80 per cent. through a No. 200 sieve.

Checking and Cracking.—Two cakes of neat cement to be moulded on glass. One to be immersed in cold water, after having set hard, and examined from day to day for surface checking and warping, the other having been set hard to be immersed in water at 212 degrees F., and allowed to remain in water of that temperature for 24 to 36 hours. Examination of the pat at the end of that time for constancy of volume and checking. Should the pats become contorted or show signs of warping or cracking the cement will be rejected.

Tensile Strength.—Neat, 24 hours, 200 pounds; 7 days, 500 pounds; 28 days, 650 pounds; mortar, 3 to 1, 7 days, 150 pounds; 28 days, 250 pounds.

The City Engineer's office, Peoria, Ill., requires:

Natural Hydraulic Cement.—All cement shall be what is commonly known as American natural hydraulic cement, of quality equal to the best obtainable in the market. It will be subject to rigid inspection and must be able to stand the following tests: Two cakes 3 inches in diameter and ½ inch thick with thin edges, will be made. One of these cakes as soon as set will be placed in water and examined from day to day. If the cake exhibits checks, cracks or contortions, the cement will be rejected. The other cake described will be used for setting and color tests. The time will be noted when the cake has become hard enough to sustain a wire 1-12 inch in diameter loaded with ¼ pound. When the wire is sustained the cement has begun to set and this time shall not be less than 30 minutes. When the cake will sustain a wire 1-24 inch in diameter with 1 pound, the test is complete, and this time must not be less than 1 hour nor more than 3 hours. The cake used for setting test will be preserved, and when examined from day to day must be of uniform color, exhibiting no blotches or discolorations. The cement must be evenly ground and when tested with the follow-

ing standard sieves must pass at least the following percentages:

No. 20 sieve, 100 per cent.; No. 74 sieve, 80 per cent. All cement for test briquettes, whether to be used neat or with sand, will be mixed with barely sufficient water to make a stiff dough or mortar. The sand for cement tests will be of such fineness that all will pass a sieve of 20 meshes per llineal inch, and none of it pass a sieve of 30 meshes per lineal inch. It will be the best quality obtainable of washed river sand. The required tensile strength per square inch shall be as follows: Neat cement, 1 day, till set in air, remainder of time in water, 60 pounds; 1 day in air, 6 days in water, 100 pounds; cement 1 part and sand 2 parts, 1 day in air, 6 days in water, 65 pounds.

FOUNDATIONS.

A few samples of specifications for cement for foundations are given; first for foundation of standpipe, used by the Water Works Department, St. Louis, Mo.:

All cement for the work herein specified shall be of the best quality of American Portland. Cement without the manufacturer's brand will be rejected without test. All cement furnished will be subject to inspection and rigorous tests of such character as the Water Commissioner shall determine, and any cement which in the opinion of the Water Commissioner is unsuitable for the work herein specified, will be rejected.

If a sample of the cement shows by chemical analysis more than 2 per cent. of magnesia (Mg O) or more than 1½ per cent. anhydrous sulphuric acid (SO_3) the shipment will be rejected.

To secure uniformity in cement of approved brands, all cement received on the work shall be subject to tests for checking or cracking and to the following tests for fineness and tensile strength:

All cement shall be fine ground and 85 per cent. shall readily pass a sieve having 10,000 meshes to the square inch.

All cement shall be capable of withstanding a tensile stress of 400 pounds per square inch of section when mixed neat, made into briquettes and exposed 24 hours in air and 6 days in water.

All cement shall be put up in well-made barrels and all short weight or damaged barrels will be rejected. Samples for testing shall be furnished at such times and in such manner as may be required. On all barrels of rejected cement inspection marks will be placed, and the contractor shall in no case allow these barrels to be used.

In measuring cement for mortar or concrete, the standard volume of a barrel of cement shall be determined by comparing its net weight with the weight of one cubic foot of thoroughly compacted neat cement.

All cement for use on the works shall be kept under cover thoroughly protected from moisture, raised from the ground by blocking or otherwise, and dry until used. The contractor shall keep in storage a quantity of accepted cement sufficient to secure the uninterrupted progress of the work.

Accepted cement may be re-inspected at any time and if found to be damaged or of improper quality will be rejected. All rejected cement shall be at once removed from the work.

Philadelphia Architects.

Portland Cement.—*Chemical Composition.*—The cement must show less than 2 per cent. of sulphuric acid and less than 2½ per cent. of magnesia.

Fineness.—Ninety per cent. shall pass a No. 70 sieve; 85 to 90 per cent. shall pass a No. 100 sieve; 68 to 70 per cent. shall pass a No. 200 sieve.

Checking, Cracking and Color.—Three cakes of neat cement are to be moulded on glass 2 or 3 inches in diameter and about ½ inch thick at the center, the edges being very thin. These cakes are to be made from a mixture of the cement and water to the consistency of a stiff plastic mortar. Cake No. 1 is to be left in the air for a determination of color. The color must be uniform throughout, of a bluish or greenish gray for Portland, and the cake must be free from yellowish blotches. The cake must show no signs of cracking or distortion after being kept indefinitely. Cake No. 2 is to be put in cold water as soon as set stiff enough for the purpose, and to remain there 2 or 3 days, when it will be put in water at 200 degrees F., and kept there for 24 or 48 hours. At the end of this time the cake should show no signs of cracking, swelling, blowing or distortion. Cake No. 2 when hard enough is to be placed in water and examined from day to day to ascertain if it becomes contorted, or if cracks show themselves at the edge.

Tensile Strength.—Neat cement, 7 days, 400 to 500 pounds; 28 days, 600 pounds; mortar, 3 to 1, 7 days, 150 pounds; 28 days, 250 pounds.

TWO ENGLISH REQUIREMENTS.

Two requirements in English type specifications for important works cover points which have heretofore not required much attention in this country, but, under the changing conditions in the cement market, may become of importance. One provides that if the rise in temperature in a sample of cement mixed with water for the purpose is more than 6 degrees in an hour after mixing, the cement is not ready for use or testing, and the other provides for aerating the cement found to be too

young, by spreading it on a perfectly dry floor in a water-tight shed near the works, not more than one foot deep, and turning it over from time to time until tests show that it has properly aged. The introduction of the rotary kiln in England and the consequent use of gypsum to temper cement reduces the latest English practice, where the cements made in this way are used, to the same basis as American practice.

THE USES OF CEMENT.

The expansion of the field occupied by cement construction is so great and so rapid that such a chapter as this requires frequent revision to keep it up to date. Many of the uses to which cement is put are considered in detail in the following chapter on Specifications for the Use of Cement. Some others may be mentioned here as well as some methods of modifying the quality, characteristics and appearance of cement for various reasons.

The first and most important use of cement is in making mortar, for brick and stone masonry and concrete. There are so many variations in materials and proportions that the chapters on Specifications can give but a part of them, those in most common use, and those chapters contain, perhaps, sufficient detail regarding the proper places to use the various mixtures. Some consideration of the cost of mortars of various proportions and of concrete may be of value, not as giving exact figures for such cost, but as giving the principle upon which an investigation may be made in any particular case. The following is from a consideration of some experiments in this line by L. C. Sabin, U. S. Assistant Engineer, in *Municipal Engineering Magazine*:

INGREDIENTS OF A CUBIC YARD OF CEMENT MORTAR AND OF CONCRETE AND THE COST.

1. The character of the ingredients used in making cement mortar varies so much that it is difficult to accurately determine the cost of a proposed mortar except by experimenting with the materials that are to be employed. The weights per cubic foot of both cement and sand vary greatly according to the conditions of packing, the moisture, etc. The percentage of voids in the sand is one of the most important variations affecting the amount of mortar made with certain materials mixed in given proportions. The consistency of the mortar also has a marked effect, and different cements show a considerable variation in the volume of mortar that a given weight will yield. In any general treatment of the question, then, we may expect only approximate results, and the discussion here given must be considered in this light.

2. The experiments, from which tables 1 and 2 are derived,* were made with a natural sand weighing 100 pounds to the cubic foot, dry, and having about three-eighths of the bulk voids. The grains varied in size from 0.01 inch to 0.1 inch in diamaeter, with a few grains outside of these limits. The consistency of the mortar was such that when struck with the shovel blade the moisture would glisten on the smooth surface thus formed. In the experiments the proportions were determined by weight, and the results for proportions by volume were deduced from them. The results for neat, natural cement mortar and for the natural cement mortars containing more than four parts sand by weight were derived by analogy.

EXPLANATION OF TABLES.

3. The first section of table 1 gives the amount of material required for Portland cement when the proportions are stated by weight; the second and third sections refer to proportions by volume of loose sand to packed cement when the size of the cement barrel is assumed at 3.65 cubic feet and 3.33 cubic feet, respectively. The fourth section gives the materials required when the proportions are given in terms of volume of loose sand to loose cement. Likewise, the first section of table 2 for natural cement refers to proportions by weight; the second, third and fourth sections, to proportions by volume of loose sand to packed cement when the cement weighs 265 pounds, 280 pounds and 300 pounds net per barrel respectively; while the fifth section refers to proportions of loose sand to loose cement.

The method of stating proportions by weight is the most accurate, but when the sand does not approximate the weight of 100 pounds per cubic foot when shoveled dry into a measure, the sections of the tables referring to weight proportions may require a correction, and it may be simpler to use the sections giving proportions by volume of loose sand to packed cement. The method of stating proportions by volume of loose sand to loose cement is to be deprecated, but since it is occasionally used provision is made for it in the tables.

In using those portions of the tables where the proportions are stated by volume it should be borne in mind that if the sand is damp when used it will weigh less per cubic foot; hence more, by measure, will be required to make a cubic yard of mortar.

COST OF MORTAR.

4. With the data given in tables 1 and 2 and a knowledge

* Annual Report of Chief of Engineers, U. S. A.. 1894, p. 2312.

of unit prices of the materials used in the mortar, one may estimate the cost of the materials in a given quantity of mortar. The cost of mixing will, of course, depend upon the cost of labor, the method employed, etc., and may vary from fifty

—INGREDIENTS REQUIRED FOR ONE CUBIC YARD OF MORTAR—PORTLAND CEMENT.

[Sand weighs about 100 pounds per cubic foot. Voids ⅜ of volume.]

Parts sand to 1 of cement.	Proportions by weight, dry sand and cement.			Proportions by volume, dry loose sand to packed cement; packed cement assumed at 104 pounds per cu. ft. or 380 pounds per bbl. of 3.65 cu. ft.			Proportions by volume, dry loose sand to packed cement; cement assumed at 114 pounds per cu. ft. or 380 pounds per bbl. of 3.33 cu. ft.			Proportions by volume, dry loose sand to loose cement; loose cement assumed at 85 pounds per cu. ft.		
	Cement.			Cement.			Cement.			Cement.		
	Pounds.	Bbls. of 380 pounds net.	Sand, cu. yard.	Pounds.	Bbls. of 380 pounds net.	Sand, cu. yard.	Pounds.	Bbls. of 380 pounds net.	Sand, cu. yard.	Pounds.	Bbls. of 380 pounds net.	Sand, cu. yard.
a	b	c	d	e	f	g	h	i	j	k	l	m
0	2,810	7.40	0.00	2,810	7.40	0.00	2,810	7.40	0.00	2,810	7.40	0.00
1	1,555	4.08	0.57	1,585	4.17	0.56	1,640	4.32	0.54	1,440	3.79	0.64
2	1,050	2.76	0.78	1,080	2.84	0.77	1,140	3.00	0.74	930	2.45	0.81
3	760	2.00	0.84	785	2.06	0.84	850	2.24	0.82	660	1.74	0.87
4	600	1.58	0.88	615	1.62	0.88	665	1.75	0.87	515	1.36	0.90
5	490	1.29	0.91	505	1.33	0.90	550	1.45	0.89	425	1.12	0.92
6	420	1.10	0.93	435	1.14	.....	470	1.24	0.91	...	...	...
7	.....	.....	.....	.....	.....	.....	410	1.08	0.93	.....	...	.....

TABLE 2—INGREDIENTS REQUIRED FOR ONE CUBIC YARD OF MORTAR—NATURAL CEMENT.

[Sand weighs about 100 lbs. per cu. ft. Voids ⅜ of volume.]

Parts sand to 1 of Cement	Proportions by weight, dry sand and cement.					Proportions by volume, dry loose sand to packed cement; cement assumed at 71 lbs. per cu. ft. or 265 lbs. net per bbl.			Proportions by volume, dry loose sand to packed cement; packed cement assumed at 75 lbs. per cu. ft. or 280 lbs. net per bbl.			Proportions by volume, dry loose sand to packed cement; cement assumed 80 lbs. per cu. ft. or 300 lbs. net per bbl.			Proportions by volume, dry loose sand to loose cement; loose cement assumed at 60 lbs. per cu. ft.				
	Cement.				Sand cubic yard.	Cement.		Sand cubic yard.	Cement.		Sand cubic yard.	Cement.		Sand cubic yard.	Cement.				Sand cubic yard.
	Pounds.	Bbls. of 265 lbs. net.	Bbls. of 280 lbs. net.	Bbls of 300 lbs. net.		Pounds.	Bbls. of 265 lbs. net.		Pounds.	Bbls. of 280 lbs. net.		Pounds.	Bbls. of 300 lbs. net.		Pounds.	Bbls. of 265 lbs. net.	Bbls. of 280 lbs. net.	Bbls. of 300 lbs. net.	
a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t
0	2,240	8.45	8.00	7.47	0.00	2,240	8.45	0.00	2,240	8.00	0.00	2,240	7.47	0.00	2,240	8.45	8.00	7.47	0.00
1	1,380	5.21	4.93	4.60	0.51	1,180	4.45	0.61	1,210	4.32	0.60	1,250	4.17	0.58	1,080	4.08	3.86	8.60	0.67
2	970	3.66	3.46	3.23	0.72	750	2.83	0.78	780	2.79	0.77	825	2.75	0.76	660	2.49	2.36	2.20	0.81
3	720	2.72	2.57	2.40	0.80	540	2.04	0.85	570	2.03	0.84	600	2.00	0.83	470	1.77	1.68	1.57	0.87
4	570	2.15	2.03	1.90	0.84	425	1.60	0.89	450	1.60	0.88	470	1.57	0.87	.....	....	....	....	....
5	470	1.77	1.68	1.57	0.87	.	..	...			.	390	1.30	0.90	.....	....	....	....	....
6	400	1.51	1.43	1.33	0.89	....	..	...	....	....	....	....	....	...	.....	....	....	....	...

cents to a dollar and fifty cents per cubic yard. If we assume for illustration that natural cement can be delivered on the mixing platform for $1.10 per barrel of 280 pounds net, that sand costs 60 cents per cubic yard and the mixing costs $1.00 per yard of mortar, then we have for the cost of a mortar composed of one part cement to two parts sand by weight,

3.46 bbls. cement at $1.10	$3.80
.72 cu. yd. dry sand at .60	.43
Cost of mixing per cu. yd	1.00
Total cost of one cu. yd. of mortar	$5.23

5. For approximate results diagrams 1 and 2 give the cost of the materials used in a cubic yard of mortar for different prices of cement. In diagram 1 the proportions by weight only are indicated, since, for Portland, the proportions by volume of loose sand to packed cement vary so little from proportions by weight. In diagram 2 the proportions of natural cement mortars are given by volume of packed cement (280 pounds net per barrel) and loose sand, as well as by weight. The diagrams are made upon the assumptions that the sand is similar to that used in the experiments recorded in tables 1 and 2, and that the cost of sand is fifty cents per cubic yard.

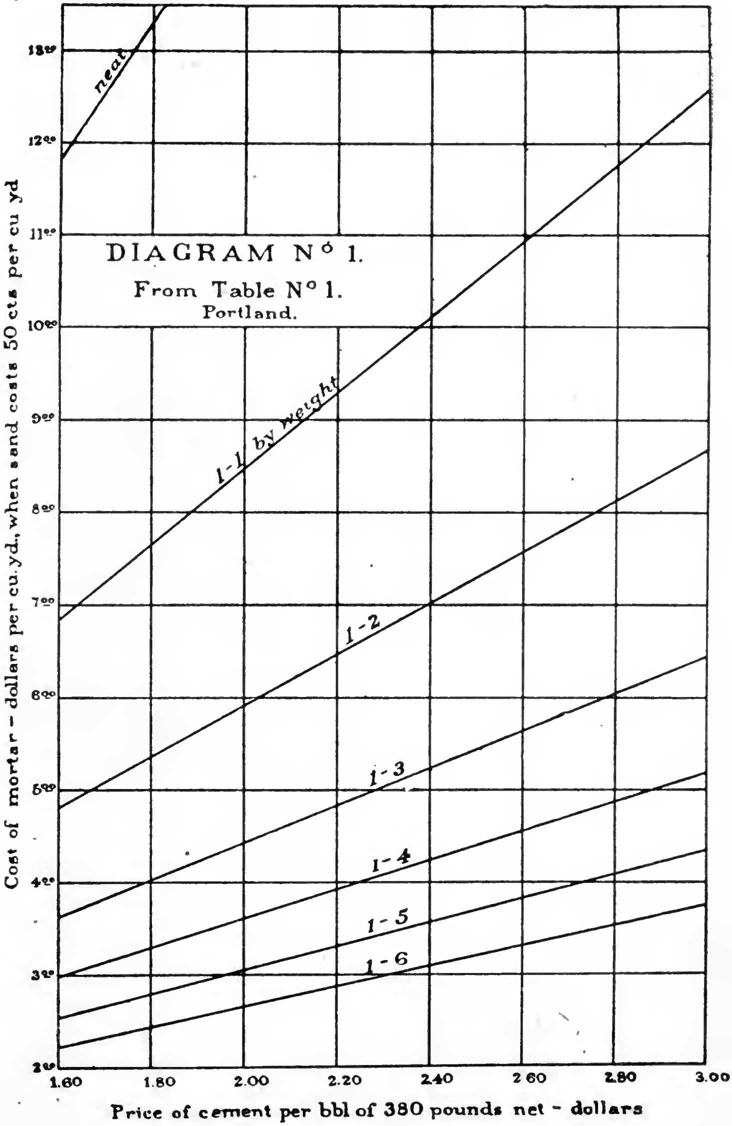
Example.

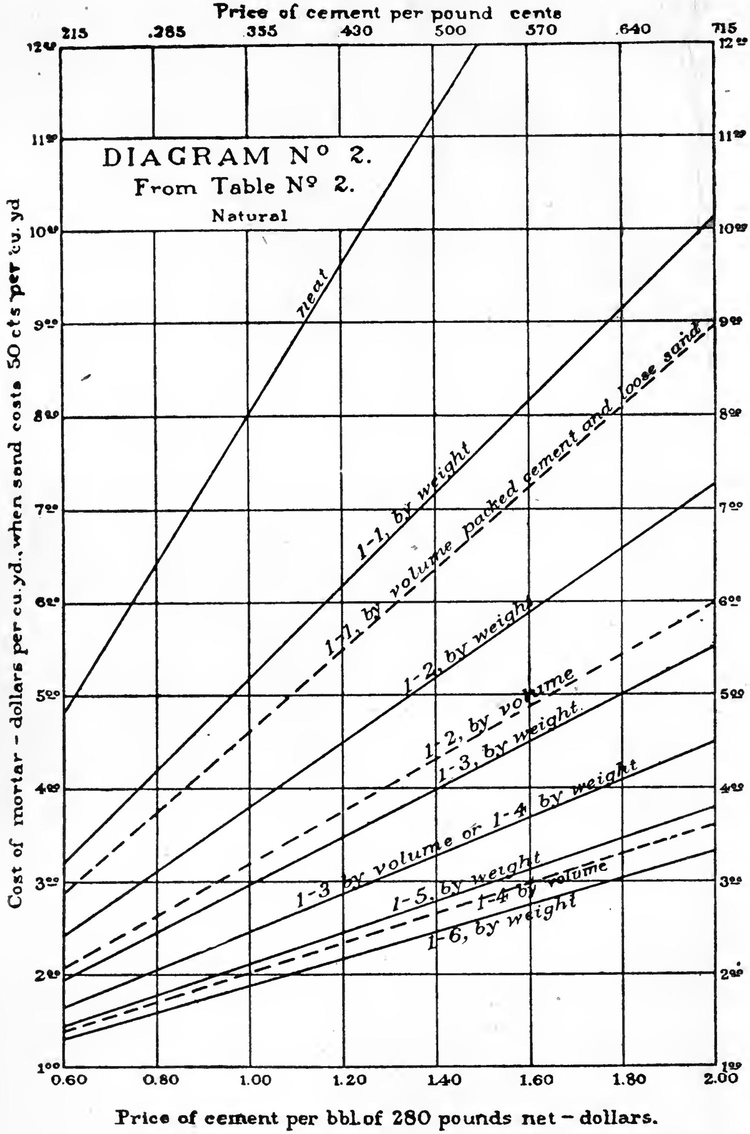
6. To indicate the use of these diagrams let us determine the cost per cubic yard of mortar containing two parts sand to one of natural cement by weight when cement costs $1.30 per barrel of 300 pounds net, and sand is thirty cents per cubic yard. One dollar and thirty cents per barrel of 30 pounds is equivalent to 0.43 cents per pound, and entering diagram 2 with this quantity, we follow the corresponding abcissa till we reach the line marked 1 to 2 by weight; we find this to be the ordinate four dollars and fifty cents per cubic yard. But in the diagram the sand is assumed to cost fifty cents per cubic yard instead of thirty cents as in the example, and as .72 cubic yard sand is used (see table), we must subtract .72 of twenty cents, or fourteen cents, from this result, making the materials for the mortar cost $4.36 per cubic yard of mortar. If the proportions were by volume of packed cement and loose sand the cost of the materials per cubic yard of mortar would be $3.75 less twenty times .78, or $3.59.

It is understood that the cost of the materials alone is given by the diagrams; the cost of mixing the materials must be added to obtain the total cost.

7. The rules given for determining the proportions of in-

gredients to use in concrete are not all to be commended, and while this article is concerned chiefly with the quantities of materials required when the proportions have been decided upon, we may suggest briefly the principle which should underlie the determination of these proportions.





8. Concrete is simply a class of masonry in which the stones are small and of irregular shape. The strength of the concrete is largely dependent upon the strength of the mortar; in fact, this dependence will be much closer than in other classes of masonry, since it may be stated, as a general rule,

that the larger and more carefully cut are the stone, the less will the strength of the masonry depend on the strength of the mortar. In deciding, then, upon the proportions of ingredients to use in a given case, the quality of the mortar should first be considered. If the concrete is to be subjected to a moderate compressive stress, the mortar may be comparatively poor in cement; but if great transverse strength is required, the mortar must be of sufficient richness; while, if the concrete is to be impervious, the mortar must possess this quality as well.

9. In making concrete the general rule should be that enough mortar be used to just fill the voids in the stone. If either less or more mortar than this amount be employed the concrete will in general be weakened thereby. The last statement is subject to one exception. If the mortar becomes stronger than the stone then an excess of mortar does not weaken the concrete; this case, however, should never be permitted to occur, the aggregate used should have a strength at least equal to that required of the concrete. It is a simple matter then to determine the required amount of mortar for a given volume of broken stone or aggregate, and the amount of cement and sand for a given volume of mortar has already been considered.

10. The bulk or volume of a given mass of broken stone is not so variable a quantity as the volume of sand. The volume of the aggregate will vary considerably with the degree of packing, but the packing is influenced appreciably by the amount of moisture present. The percentage of voids in the aggregate may be determined as follows: Obtain the weight per cubic foot of the broken stone in the condition in which the percentage of voids is sought. Also obtain the specific gravity, and hence the weight per cubic foot, of the solid stone. Then one, less the quotient obtained by dividing the weight per cubic foot of the broken stone by the weight per cubic foot of the solid stone will be the proportion of voids in the former. Another method is to fill a vessel of known capacity with the aggregate to be used, and to pour in a measured quantity of water until the vessel is entirely filled. The volume of water used indicates the necessary quantity of mortar. In using this method the stone should be moistened before placing in the vessel to avoid an error from the absorption of the water used to measure the voids.

11. As to the degree of jarring or packing to which the stone should be subjected in filling, if the stone is put in loose, and it is proposed to ram the concrete in place, the amount of mortar indicated will be somewhat more than the

required quantity; if the concrete is to be deposited without ramming (as in submarine construction), the amount of mortar indicated will not be too great. On the other hand, if the aggregate is shaken down in the vessel to refusal, the voids obtained will be less than the amount of mortar which should be used, because it is not possible to obtain a perfect distribution of mortar in a mass of concrete, such that the concrete will occupy the same space as did the broken stone when thoroughly shaken. And again, for perfect concrete, pieces of stone should be separated one from another by a thin film of mortar, and hence the volume of the concrete will be greater than the volume of the aggregate measured in compact condition without mortar. A deficiency of mortar is usually more detrimental than an excess. It is, therefore, safer to measure the voids in the stone when but slightly jarred and make the amount of mortar correspond to the voids so obtained.

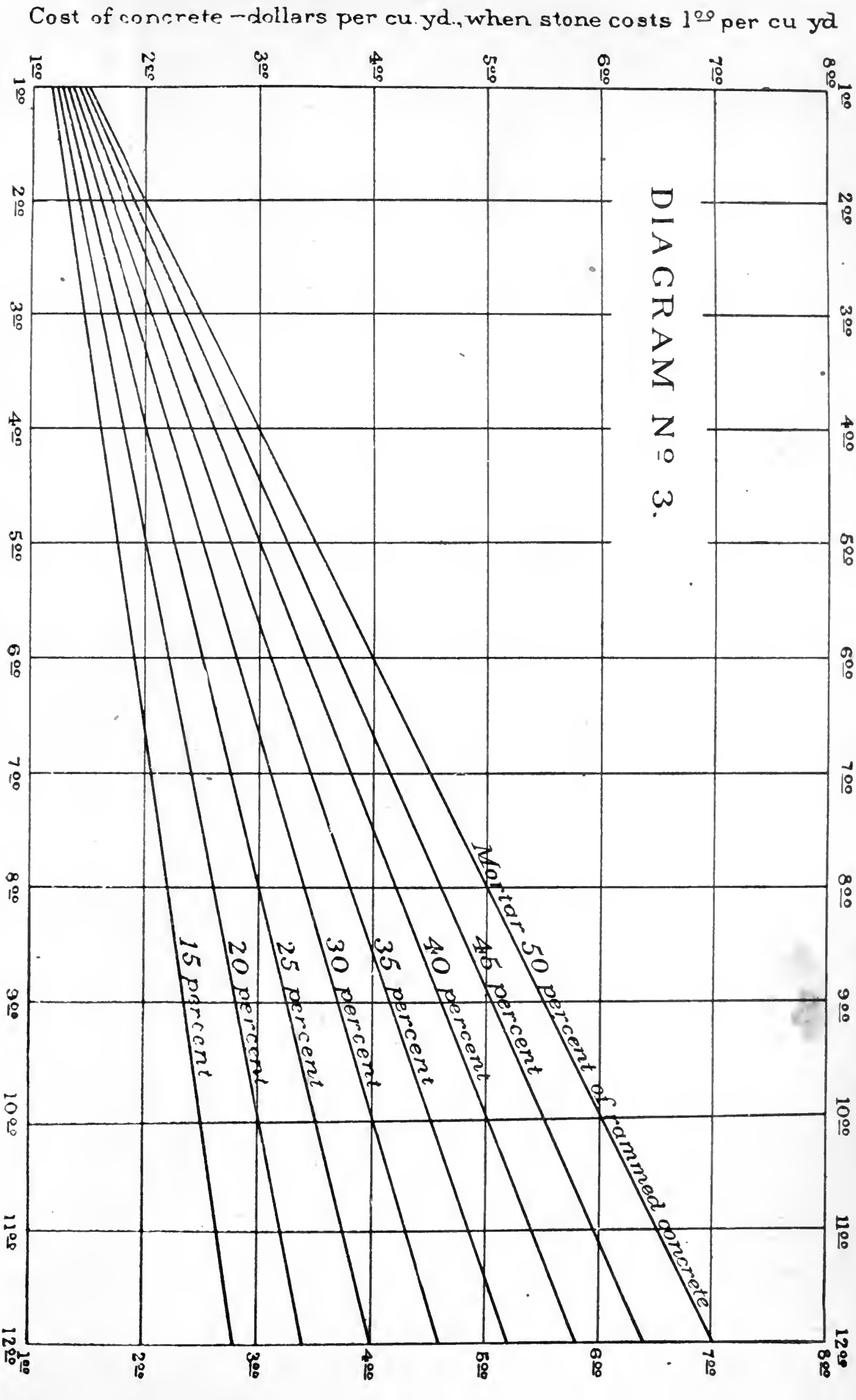
12. We may say, then, that the rational method of proportioning concrete is to let the duty required of the concrete fix the quality of the mortar, and let the quantity be sufficient to fill the voids in the aggregate. Knowing the percentage of voids in the aggregate, and consequently the percentage of mortar which should be found in a cubic yard of the finished concrete, we may obtain the approximate cost per cubic yard of the latter for a given quality of mortar and given unit prices.

Thus, suppose we have stone in which the voids are such that the mortar will amount to 40 per cent. of the finished concrete, and we wish to have the mortar composed of two parts sand to one part natural cement, by weight, unit prices being as follows:

Cement,	$1.30 per bbl. of 300 pounds, net
Sand,	.30 per cubic yard.
Stone,	1.25 per cubic yard.

As in paragraph 6 we find the ingredients in one cubic yard of mortar to cost $4.36. Since 40 per cent. of the concrete is to be mortar, the mortar in one cubic yard of concrete will cost 40 per cent. of $4.36, or $1.75, and one yard of stone at $1.25 will make the total cost of the materials in the concrete $3 per cubic yard.

13. Diagram No. 3 may be used to get the approximate cost of the concrete after having obtained the cost of the mortar from either diagram 1 or 2. Thus, if we enter diagram 3 with cost of mortar $4.36, and follow the abcissa to the diagonal line marked 40 per cent., we find this to be on the ordinate $2.75, the cost of the ingredients in a cubic yard of the


Cost of concrete —dollars per cu. yd., when stone costs 1.00 per cu yd
DIAGRAM No. 3.
Mortar 50 percent of rammed concrete
45 percent
40 percent
35 percent
30 percent
25 percent
20 percent
15 percent
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
11.00
12.00

concrete when the stone costs $1 per cubic yard. Hence, $2.75 + $0.25 = $3, the approximate cost of the materials in a cubic yard of the finished concrete as desired. The qualification "approximate" is used advisedly, because it is well known that since the amount of concrete made from given quantities of ingredients is subject to slight variation from so many causes, accurate estimates of cost are not possible.

14. The usual method, however, of stating proportions in concrete is to give the volume of sand and stone to one volume of cement. Thus, one of cement, three of sand and six of stone, would usually mean one volume of packed cement, three volumes of loose sand and six volumes of loose broken stone. When proportions are thus arbitrarily stated, we may determine, from the tables and diagrams already given, the amount of water which a given quantity of dry ingredients will make, and the consequent cost of the mortar per cubic yard. Then a knowledge of the voids in the broken stone will permit of a close estimate of the amount of concrete made, whence the cost of the latter.

For example, suppose it is desired to determine the cost of materials in a cubic yard of natural cement concrete under the following conditions:

One bbl. cement eontaining 280 pounds net at $1 per bbl.
Three bbls. sand weighing 100 pounds per cubic ft. at $0.75 per cu. yd.
Six bbls. loose broken stone having 45 per cent. voids at $1.25 per cu. yd.

1 bbl. cement—3.75 cu. ft.—0.239 cu. yd. cost	$1.000
3 bbls. sand—11.25 cu. ft—.417 cu. yd. cost	.313
6 bbls. stone—22.50 cu. ft—.833 cu. yd. cost	1.041
Total cost	$2.354

From table 2 we find that it requires 2.03 barrels of cement to make one cubic yard of one to three mortar; then one barrel of cement would make 0.493 cubic yard. As 45 per cent. of the stone is voids the amount of solid stone in six barrels of broken stone would be $.833 \times .55 = .458$ cubic yard. Then the mortar plus solid stone would be $.493 + .458 = .951$ cubic yard. It has been found by experiment that the amount of concrete made will usually exceed the sum of the mortar and solid stone by from two to five per cent., hence we may assume in this case that .98 cubic yard concrete resulted from the above materials and $2.354 \div .98 =$ $2.40, the cost of the material in one cubic yard of finished concrete. To obtain the actual cost of concrete in place, the cost of mixing and deposition must be added.

The following table prepared by Mr. C. E. Fowler shows the amounts of each material required to make one cubic yard of

Portland cement concrete with various proportions of cement, sand and stone. It is made by comparison with actual cases and gives very satisfactory results in practice.

Proportions.	Barrels Cement	Cu Yds. Sand.	Stone 0.4 voids	Stone 0.5 voids.
1-2-3	1.77	0.51	0.85	1.05
1-2-3½	1.68	0.49	0.81	1.10
1-2-4	1.59	0.47	0.95	1.15
1-2-4½	1.48	0.44	1.00	1.20
1-2-5	1.39	0.42	1.04	1.26
1-2-5½	1.30	0.40	1.08	1.30
1-3-4	1.30	0.57	0.83	1.00
1-3-4½	1.22	0.54	0.89	1.06
1-3-5	1.16	0.52	0.92	1.11
1-3-5½	1.09	0.50	0.97	1.16
1-3-6	1.04	0.48	1.00	1.20
1-4-6	1.00	0.55	0 91	1.09
1-4-6½	0.96	0.55	0.94	1.13
1-4-7	0.92	0.51	0.67	1.17
1-4-7½	0.88	0.49	1.00	1.21
1-4-8	0.83	0.47	1.03	1.25

The heavy lines are put in the table to aid in selecting those mixtures in which the voids of the stone are completely filled and those which are but partly filled.

William B. Fuller's rule for determining the quantities of ingredients in a cubic yard of concrete for various proportions is as follows:

The sum of the proportions of cement, sand and stone is taken and the number 11 is divided by this sum. The result is the number of barrels of Portland cement required for a cubic yard of concrete. The proportions are stated in the usual form, one part of cement to assumed numbers of parts of sand and stone. The number of barrels of cement multiplied by the proportion of sand and by 3.8, the number of cubic feet in a barrel, and the product divided by 27, gives the number of cubic yards of sand required and a similar computation gives the number of cubic yards of stone.

The results of this formula may be compared with Mr. Fowler's table, above, and will be found in substantial agreement as to quantity of cement, being usually larger for rich concrete and less for leaner concrete. It will be noted, also, that the formula would give the same amount of cement for a 1:2:5 mixture as for a 1:3:4. The same may be said regarding the quantity of sand, except that for the richer concretes the formula reduces the amount of sand. For broken stone the for-

mula gives results about 8 per cent. less than the table.

A paper on the Theory of Concrete, by George W. Rafter, before the American Society of Civil Engineers, describes some experiments made by him. Concrete blocks made part with mortar equal to 33 per cent. of the stone and part with 40 per cent. were made, part with the dryest mixture possible, part with enough water to make the mixture plastic, and part with an excess of water. Four brands of natural cement and two brands of American Portland cement were used. In all, 173 blocks of concrete, each one cube foot, were made and crushed.

The blocks made with 40 per cent. of mortar and an excess of water averaged 2,227 pounds crushing strength per square inch, with plastic mortar 2,329 pounds, with dry mortar 2,532. A similar ratio exists in the case of 33 per cent. mortar. The 40 per cent. concrete averaged 4 per cent. stronger than the 33 per cent. This excess of strength was as high as 7 per cent. with mortar made of one part cement to two parts sand, and there was no excess with mortar of 1 to 4.

In a paper before the Indiana Engineering Society, Mr. S. B. Newberry discusses the relations of the proportions of materials to the strength of concrete, and makes several points which are in effect as follows: The purpose in combining the sand, gravel and broken stone is to produce the greatest possible density, which can be accomplished by adjusting the proportions of the finer material to fill the voids in the coarser material as completely as possible. The variety of sizes from smallest to coarsest must be the greatest possible. Screening is undesirable between these limits unless by separating and remixing better proportions can be obtained. Voids in various materials were reported as follows:

Sandusky Bay sand, not screened	32.3 per et.
Kentucky sand	31 per ct.
Gravel ¼-in. to 1-20 in	35.0 per ct.
Gravel passing 1½-in. screen and freed from sand by a fine screen	35 per ct.
Broken stone, 1-in. to 2-in., from Marblehead, O	47 per ct.
Broken stone, 2½-in. and less	48 per ct.

Voids in broken stone can be found by the weight of water a given volume will contain. Voids in sand are best obtained by comparing the weight of a given volume with the weight

of a similar volume of the solid rock, as derived from the specific gravity of the sand material.

From a paper by Dyckerhoff before the German Portland Cement Manufacturers' Association, Mr. Newberry quotes the following table showing greater strength for less proportion of cement up to the limit of proportion of voids:

Portland Cement	Sand	Gravel	Strength under compression in lbs. per sq. in.
1	2	....	2,125
1	2	3	2,747
1	2	5	2,387
1	....	5	978
1	3	....	1,383
1	3	5	1,682
1	3	6½	1,515
1	4	....	1,053
1	4	5	1,273
1	4	8½	1,204

Mr. W. B. Fuller's rule is quoted with approval, to "mix the sand and stone or gravel in a definite fixed proportion as determined by experiment for the material in use and add cement as economy dictates, possibly up to 10 per cent. in excess of the voids in the combined material." Using the materials above named, the theoretical proportions of cement, sand and gravel for the best concrete would be 1, 3.1 and 8.6, and for cement, sand and broken stone, 1, 3.1 and 6.5. In practice the proportion of sand should be increased slightly. These concretes will give a crushing strength of over 2,000 pounds a square inch after 28 days, and can be increased in strength to 4,000 or 5,000 pounds by increasing the proportion of cement. Increasing the proportion of sand at the same time will make the increase in strength less noticeable. The mixture 1 cement, 3 sand, 8½ gravel is stronger than the mortar without the gravel. Wet concrete is preferred.

The yield of concrete for given quantities of materials, using gravel with 35 per cent. voids is reported by Dyckerhoff as follows:

Cement	Sand	Gravel	Concrete
1	2	4	4.4
1	3	6	6.65
1	4	8	8.85

Were the proper proportion of sand to fill the voids used, the resulting volume of concrete would be nearer equal to the volume of gravel.

Professor W. K. Hatt reported some results of tests with natural hydraulic cement showing similar increase in strength for the complete filling of voids in sand. For 28 days' age of cubes, mixtures of one part Utica cement, two parts of sand and varying proportions of broken stone gave the following results for compressive strength per square inch: Four parts stone, 680 pounds; five parts, 910 pounds; six parts, 610 pounds; seven parts, 600 pounds. Similar results for other times of setting, from 1 day to 6 months, were observed.

Practice is not yet settled as to the factor of safety to be used, and it must depend to some extent upon the local conditions, but in general it may be said that the safe loads for various kinds of concrete may be obtained by dividing the figures for crushing strength given in this book by from 6 to 8, unless the structure is subject to vibration, in which case 10 to 12 should be the divisor.

Variation in volume of cement packed and loose makes much difference in proportions of cement in mortar, a point which is frequently neglected in carrying out specifications, even when it is properly taken care of in the specifications themselves. In regard to this reference may be made to the specifications for concrete of the Chicago & Alton railroad in the chapter on "Specifications for the Use of Cement," and also to the chapter on "Data for Estimates."

The excess in cost of laying a cubic yard of concrete with dry mortar over that with wet mortar is shown by Herman Conrow by figures from actual experience, as follows:

	Cost of Laying Wet Concrete.	Cost of Laying Dry Concrete.
Cement (1 barrel Portland)	$1.50	$1.50
Sand	.50	.50
Stone.	1.00	1.00
Labor	1.13	2.12
Totals	$4.13	$5.12

The gang for wet concrete was 1 foreman, 9 mixers, 1 rammer, laying 15 cu. yds. a day. For dry concrete, 1 foreman, 6 mixers, 4 rammers, laying 8 cu. yds. a day. The foreman received $2 and the men $1.50 a day.

The question of the use of gravel in place of broken stone in concrete frequently arises. Experiments reported in the report of the Engineer Commissioner of the District of Columbia for 1897 indicate that with natural cement the gravel concrete has one-half to three-fourths the strength of broken stone concrete, and with Portland cement there is but little difference, the experiments being somewhat in favor of broken stone. It is noticeable that there is a material increase in the relative strength of gravel concrete with age so that if the concrete is not to receive its load for some months it will be very nearly as good as that made with broken stone.

Mr. C. R. Neher, in a paper before the Engineers' Society of Western New York, reports tests of the compressive strength of concrete of various materials as follows: in proportions of 1 cubic foot of Portland cement to 2¾ cubic feet of limestone between ½-inch and 2-inch screens and 2½ cubic feet of lake gravel, the ultimate compression after 7 days was 135 tons per square foot. A mixture of one part Portland cement with five parts of gravel gave 60 tons per square foot after 7 days. Copper slag in place of the limestone gave 80 tons, but with the amount of gravel reduced slightly, as the breaks showed excess of gravel in spots, the slag concrete reached an ultimate compressive strength of over 140 tons per square foot in 7 days. Where weight is desired the slag is valuable, as it weighs 3,300 pounds per cubic yard for run of crusher against 2,800 pounds assumed for limestone.

A discussion of the effect of size of sand upon the strength of mortar by Mr. A. S. Cooper leads him to the conclusion, based on experiments by himself and several others, that coarse sands produce stronger mortar than fine sands up to the size passing a No. 12 sieve and refused by a No. 16. Sand passing a No. 50 sieve is all practically without variation in its effect upon the strength of mortar. The shape and condition of the surfaces of the grains of different sands have as much to do with their value for cement mortar as the size, rough grains like crushed trap rock and granite being better than those with smooth surfaces, and river sand being better

than beach sand. The proportions of mortar used in the tests were usually one to one.

The effect of increase in amount of sand in mortar was shown by a series of experiments at the Holyoke dam, Massachusetts, upon an American Portland cement of the highest grade. The results for tensile strength of mortar of various proportions at the end of 28 days set in water were as follows:

Sand to Cement.	Lbs. per sq. in.	Sand to Cement.	Lbs. per sq. in.
Neat cement	889	5 to 1	133
1 to 1	805	6 to 1	121
2 to 1	589	7 to 1	71
3 to 1	343	8 to 1	53
4 to 1	204	9 to 1	44

The effect upon strength of varying proportions of aggregates in cement is shown by the following values for the modulus of rupture of concrete beams in pounds per square inch, selected by Taylor and Thompson from William B. Fuller's experiments on 6-inch beams: In each case the proportion of cement to total aggregate is 1:6. If the proportions of cement, sand and broken stone by weight are 1:1:5, the modulus is 504 pounds; if 1:2:4, the modulus is 439 pounds; if 1:3:3, the modulus is 355 pounds; if 1:4:2, the modulus is 210 pounds; if 1:6:0, the modulus is 93 pounds.

VARIATIONS IN QUALITIES OF MATERIALS FOR CONCRETE.

Broken stone and gravel are compared in what has gone before. Other comparisons follow.

In a paper before the Engineers' Society of Western Pennsylvania, Mr. Joseph A. Shinn describes the formation of what he terms slag sand, by cooling the molten slag from blast furnaces with jets of water under pressure. He gives a number of comparisons of the strength of this material in mortar with river sand in the same proportions. His tests show that the tensile strength of mortars made of one part Portland cement and three parts slag sand are from 26 pounds at 7 days to 159 pounds per square inch at 3 months stronger than river sand mortars of same proportions and ages. These increases in strength are respectively 10.3 and 36.5 per cent. above the strength of river sand mortars. With Louisville cement the

gain with slag sand is not so pronounced, varying from 15 pounds or 34 per cent. at 7 days to 25 pounds or 21 per cent. at 3 months. With lime mortars the increase is materially greater, soft mortars with slag sand gaining 114 pounds or 771 per cent. at 28 days and 139 pounds or 580 per cent. at 3 months; stiff mortars show gain with slag sand of 126 pounds or 371 per cent. at 28 days and 208 pounds or 441 per cent. at 3 months.

Numerous experiments in the laboratory and in practical use have shown some increase in the strength of mortar made with clean limestone screenings containing a considerable percentage of crusher dust in place of sand. Nelson A. Hallett reports laboratory experiments in which he used the screenings passing a sieve with 100 meshes to the square inch, containing about 33 per cent. of fine dust. A rather wet mixture, 15 per cent. of water to 1 part of cement and 2½ parts of screenings by volume, thoroughly mixed and tamped as concrete is tamped gave results "easily 50 per cent. stronger than the best sand mortar that could be obtained." These are results of five years of experiment, some of the briquettes having been kept three years in water.

The usual specification for sand requires that it be clean, sharp, free from loam, clay or organic matter. The successful use of sand containing from 3 to 7 per cent. by volume of alkaline earth and organic matter in building the "Golden Gate" viaduct in Yellowstone National Park, led Prof. C. E. Sherman to make some experiments upon the effect of loam and clay upon mortar. Dyckerhoff and Lehigh cements were used in proportions of 1 of cement to 3 of sand. The standard sand of the American Society of Civil Engineers, sand from Lake Erie and bank sand were used. Part of the sand was displaced by Mayfield, Ky., ball clay in some of the briquettes, 2, 4, 6, 8, 10 and 15 per cent. being used respectively. In another set the same percentages of loam, common field soil from a field in the Ohio State University campus, were used. Roughly stated, the addition of 15 per cent. of clay increased the tensile strength of briquettes 50 per cent. at 1, 2, 3, 4, 5, 6, 9 and 12 months, there being some variations above and below. Also roughly speaking, the increases in strength were approx-

imately proportional to the percentage of clay in the sand. With more variations in individual results, similar statements will apply to the substitution of loam for part of the sand, the maximum increase in strength being about 25 per cent. with 15 per cent. of loam at 12 months. Of the different kinds of sand, bank sand stood highest, the standard next and lake sand last in about the average proportions of 6, 5 and 4.5.

Mr. J. C. Hain made for the Chicago, Milwaukee & St. Paul railroad during three years many tests of sand from various pits along the lines of the system to determine what sands would be satisfactory for use in concrete work. He presented a paper before the National Association of Cement Users, giving the results of his observations from which the following conclusions are taken:

To sum up the situation, it is quite evident that clay in limited quantities (say not to exceed 12 per cent.) is beneficial if thoroughly distributed throughout the sand. Before using, however, it ought to be compared with an established standard.

Soil, on the other hand, is detrimental. Sand containing it shows up irregularly. Such sand should prove satisfactory by tests before using.

Washed sand may be less desirable than unwashed. Washing removes the fine particles as well as the foreign material. The fine grains, if not in excess, are needed to fill the voids of the larger.

The only safe way to decide whether sand ought to be washed would be to test it under both conditions.

A fine sand may show up well if the grains are well graded. A coarse sand may show up poorly if there are too few fine particles to fill the voids. The best graded sand is one in which the grains held on a uniform series of sieves are so arranged that the voids in one lot are filled, and not overfilled, by the grains in the next smaller size, and so on. This grading should begin with large grains in order to limit the surfaces exposed to cement, and still these grains must not be so large that the voids will not be filled with the smaller particles.

Briefly, then, the best mortar sand found in nature is one with sharp corners, rough surfaces, with grains neither coarse, medium nor fine, but with the proper mixture of all these sized particles which will result in the least voids. The sand also should not be washed, but may contain up to 12 per cent. of clay which will not injure but will perhaps improve it.

Edward K. Coe, Assistant City Engineer, Duluth, Minn.,

gives in a report to the City Engineer the following results of tests, giving some indication of the proportion of clay which may be used to advantage:

The sand used was standardized Lake Superior "clean, sharp sand." The clay was red, dried, pulverized and thoroughly incorporated with the sand. The results here given are averages of four and eight breaks each.

1 to 5 mortar, standardized sand, Atlas cement:

Age 7 days.	Age 28 days.	Per Ct. clay in the sand.
135	211	none.
172	279	8
175	284	13½
153	220	21

1 to 5 mortar, Universal cement:

Age 7 days.	28 days.	3 mos.	1 yr.	
140	176	252	310	Clean sand.
203	301	402		10 per ct. clay in sand.

The following were made with an excess of water, and too soft to ram.

1 to 5 mortar, Universal cement:

Age 7 days.	28 days.	3 mos.	1 yr.	
104	180	204	251	Clean sand.
90	161	250	317	15 per ct. clay.

He says also that Louisville natural hydraulic cement in every case gives the highest results with clear sand.

Mr. C. C. Huestis, Asso. M. Am. Soc. C. E., suggests in Engineering News that the fact that crusher dust, clay or loam increased the strength of mortars made of 1 part cement and 3 parts sand, but diminished the strength of 1 to 2 mortar, led him to the conclusion that the increase in strength is due to the more complete filling of the voids in the sand by the fine material so that the proportion of cement used was sufficient to make the mass solid, while if the fine material is not retained the cement is not sufficient in volume to fill all the voids. Clean sand in mortar of proportions of 1 to 2 has its voids completely filled by the cement and the addition of fine material simply increases the proportion of sand in the mortar and reduces the strength of the mortar in about the same proportion. Washed sand in proportions of 1 to 3 or more does not have its voids completely filled with cement. The con-

crete is therefore not homogeneous. Fine stone dust, clay or even loam adds more to the strength of the mortar by reducing the percentage of voids to what the cement can fill than it deducts from it by reason of its quality. It will be noted that all the experiments described above are upon mortars of 1 cement and 2½ to 5 of sand.

MORTARS OF CEMENT AND LIME.

The demand for mortars for building purposes containing proportions of cement and lime has led the manufacturers of Louisville natural hydraulic cement to put on the market "Bricklayer's Cement," which is made by grinding 15 per cent. of hydrated lime with calcined cement stone to a fineness of 92 to 95 per cent. through a No. 100 sieve.

Mr. E. S. Wheeler made some experiments to determine the effect of lime upon Portland cement mortar, using proportions of cement of 1:3 to 1:6 and percentages of lime to weight of cement of 10 to 50. The addition of 10 per cent. of lime to the 1:3 mixture increased the tensile strength of the mortar at 3 months from 236 pounds per square inch without lime to 265 pounds with it. The substitution of 10 per cent. of lime for the same weight of cement, making the proportion of cement to sand 1:3 1-3 and of cement and lime together to sand 1:3, gave a strength of 264 pounds per square inch. Further increase in proportion of lime decreased the strength of the mortar quite rapidly.

The lime must be thoroughly hydrated. Unslaked lime in mortar may produce expansion of mortar or concrete and subsequent disintegration.

CEMENT SIDEWALKS AND FLOORS.

Development of the use of cement in sidewalks has been very rapid, and hundreds of miles of new walks are constructed each year. Its use for this purpose has spread to the smallest towns, which have in many cases constructed several miles each in a single season. Full specifications as prepared for use under the conditions in different parts of the country will be found in the next chapter.

The question of foundation is one of much interest and there are many expressions of opinion as to the depth of foun-

dation necessary. The specifications in the next chapter show what various engineers consider necessary. Albert Moyer, of the Vulcanite Portland Cement Company, prepares three specifications under the following principles:

In laying a cement sidewalk keep constantly in view the fact that the form of construction is artificial stone slabs or flags, each slab subject to all the conditions surrounding artificial stone, such as careful selection of materials, thorough mixing, tamping and seasoning, allowance in the joints for expansion, upheaval by frost and wear. Portland cement concrete expands and contracts with temperature changes in practically the same ratio as steel. Upheaval by frost is obviated by providing an under drainage.

Specifications Nos. 1 and 2: Sidewalks in cold climates or where frost occurs, should consist of a foundation of coarse cinder or broken stone extending below frost line, a concrete base and a top coat or wearing surface.

Specification No. 3 for cement sidewalks in warm climates where freezing does not occur: Excavate to a depth of 4 inches below established grade of the sidewalk, tamp the ground well and evenly, omit the cinder or broken stone drainage foundation; remainder of specification same as that for sidewalks in cold climates.

With reference to the amount and quality of sand to be used in the wearing surface of cement walks the following paragraph from a letter by U. S. Assistant Engineer A. S. Cooper, in Engineering News, is valuable:

A walk with a surface of neat cement is not as durable as one with a mortar of one cement to one sand, because the cement is not as hard as the sand; and a mortar of one cement to one sand is not as durable as one of one cement to two sand, because in the former case the voids are more than filled and some of the cement forms part of the wearing surface, and will therefore wear out quicker than the mortar which has a complete wearing surface of sand. The strength is derived from the concrete below, and the life of the walk is entirely dependent upon the hardness of the surface. The most durable sidewalks are made from crushed trap rock, using the small rock for concrete, and the finer particles with the dust screened out, as sand for the mortar. This is not only the strongest mortar and concrete that can be obtained, but also makes a very hard surface, that will resist wear better than any other sand. In making the mortar for the wearing surface the writer would advise the use of a large percentage of coarse sand, say 50 per cent. held on a 20 mesh sieve.

He also objects to the use of limestone screenings in the wearing surface, as limestone is softer and less durable than sand grains; but would permit the limestone screenings in the base.

In England flagstones for sidewalks are made in factories and set in place. The aggregates used are crushed granite and limestone, also the clinker from garbage cremation plants. The use of steel reinforcement, such as wire netting, expanded metal, bars, etc., in such flags has not yet extended very far, and in this country the making of the walks in place is so much more popular that the making and laying of concrete flags is seldom heard of.

The use of natural hydraulic cement in the base of walks and floors and of Portland cement in the wearing surface is recommended by some contractors who have had good results with this combination, but the great majority of those who have experimented in this method of construction report failures. The great differences in rate of setting, in expansion or contraction in crystallizing and even in chemical actions set up strains which are often too great for the walk to stand, and the two kinds of concrete are separated from each other or one or the other is cracked and by the aid of the weather is ultimately disintegrated.

Many inquiries are received asking the best method of repairing or renewing a cement walk or floor, the surface of which has been worn off or broken on account of hard usage or defective construction. The replacing of the wearing surface without removing the base and replacing the entire thickness of concrete is difficult. There is occasionally a cement worker who meets with success, but usually the permanency of the repair can not be predicted. The essentials seem to be perfect cleanliness of the old concrete surface, all loose particles and dust being completely removed, thorough wetting of the old concrete, a thin coat or wash of neat Portland cement on this wet surface, followed, before the cement has set, with the wearing surface coat.

The use of cement for concrete floors in stables, cattle and hog pens, breweries and factories, where a smooth, durable surface is required, has developed equally with its use for

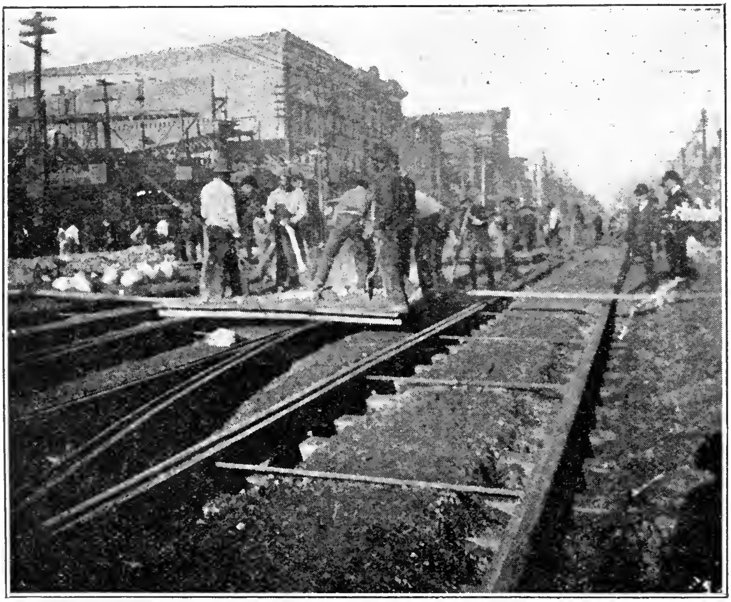
sidewalks. It makes an ideal floor for almost all such purposes, is easily repaired when cut entirely through for any purpose, and is practically indestructible when properly constructed, except for wear of traffic. Special care must be taken to allow for expansion and contraction when there are great variations in temperature, and special construction to insure water-tight joints is necessary in such cases. Ample joints filled with asphalt or similar elastic and water-proof material are nearly always satisfactory. In case a floor must be at the same time water-proof, a layer of continuous asphalt or other water-proofing under the concrete blocks will answer the purpose. Slight inclination toward one side or corner or outlet conveniently placed will often aid in removing the liquid reaching the asphalt layer and thus reduce the cost of repairs. There are several special devices for laying wooden floors in stalls where horses stand, to add to their comfort and protect the concrete from the constant wear of their steel shoes. The wooden portions should be readily removable for cleaning and renewal.

CONCRETE ROADWAYS.

Street crossings of cement concrete are made in some smaller cities whose streets are not paved, and they are a sufficient improvement over the usual wood or flag stone crossing to repay the increase in cost. They are made according to the specifications for driveways in the next chapter, with wings or approaches on each side, on a slight slope, extend down into the earth on each side a distance depending upon the depth of mud in wet seasons, that wagon wheels may not strike the edges of the concrete and disintegrate them.

Pavements for driveways to public and private stables, to railroad freight stations, factories, storehouses, etc., are equally valuable and their use is rapidly increasing.

In New Orleans the neutral ground on Canal street was paved with concrete in 1901. This neutral ground is 60 feet wide in the center of a street 170 feet wide and contains five street car tracks. Concrete is placed under the railway tracks and between the ties and on top is laid 4 inches of concrete of one part Portland cement, three parts sand and seven parts



TRACK CONSTRUCTION. NEW ORLEANS CONCRETE PAVEMENT.

NEW ORLEANS CONCRETE PAVEMENT.

broken stone with one inch top layer of one part Portland cement and one part sand. Sand joints in the concrete and tar paper joints in the top divide the pavement into blocks and there are 8-inch sand joints next the rails as shown in the accompanying cuts. The cost was 25 cents a square foot. Complaint has been made of the excessive heat from the reflection of the sun and it has been found necessary to keep the pavement wet on this account during the hot season.

In 1903 City Engineer W. J. Hardee reported upon failures in some portions of the pavement, attributing some of them to settlements in the railway tracks extended by the vibrations of running cars under the changed conditions produced by the settlement. Some of the pavement failed because the top course was not thoroughly bonded with the bottom course and the great heat to which the pavement surface is subjected in summer separated the two layers on account of the weakness of the junction, which could not stand the strains set up by the differences in expansion of top and base. Part of the top course was delayed so that it could not be laid before the base had set. Some of the area thus delayed is in good condition, showing good bond of base and top, while part of it has failed as described. This pavement is not subjected to vehicle traffic.

The city of Bellefontaine, O., has constructed several blocks of concrete pavement, the first of which, laid about 1890, is still in very fair condition. The specifications for the pavement were practically the same as those for cement driveways given in the next chapter. A square yard of the pavement required 144 pounds of cement and 4 cubic feet of gravel.

Grand Rapids, Mich., has recently built several short concrete pavements on narrow streets on similar specifications.

Toronto, Canada, has laid several concrete pavements with specifications and cross sections as shown in the next chapter. Richmond, Ind., has entered upon this class of construction and quite full specifications are given in the same place.

In various parts of England, Germany and other European countries concrete macadam pavements have been laid, made of 1 part Portland cement and 4 parts broken stone, laid in two layers each 3 or 4 inches thick in the center of the street and 1 inch thinner at the sides. Some of them have failed promptly

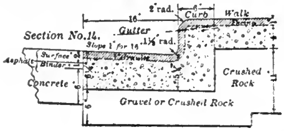
and some have lasted ten years without repairs, but they are not popular.

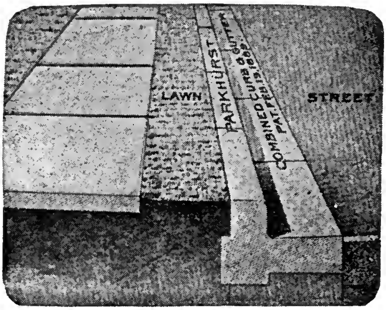
CURB AND GUTTER.

Since the invention of the Parkhurst combined curb and gutter the use of cement for making street curbing has increased very rapidly. Over 120 miles of the Parkhurst curb and gutter alone have been constructed during the last ten years. and many miles of concrete curb and gutter and of curbing alone. The combination of curb and gutter solves a problem for macadam streets by giving a smooth gutter for drainage, and for asphalt by removing the danger of injury to the asphalt surface by water standing in flat or in obstructed gutters. The appearance of well-constructed curb is much in its favor, and it is more durable than most kinds of natural stone, the use of which is popular in some districts. The addition of strips of steel to take the wear on edges and face is made with success where the amount or character of traffic makes this precaution necessary for either stone or concrete curb, and the metal is most easily put in place and kept there when the cement curb is used.

The following diagrams show two somewhat different methods of laying concrete walk, curb and gutter.

CROSS-SECTION OF COMBINED CEMENT CURB AND GUTTER

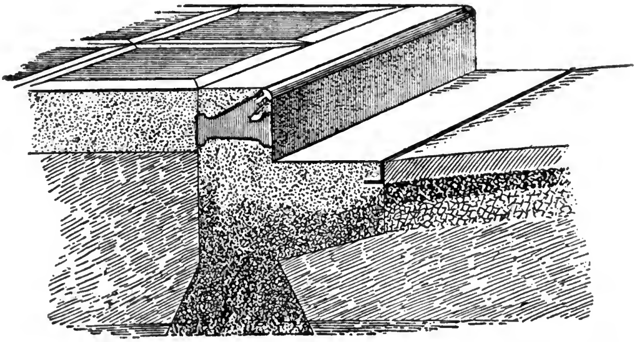




TWO DESIGNS FOR CONCRETE WALK, CURB AND GUTTER.

In a description of the construction of the Forbes Hill reservoir at Quincy, Mass., Mr. C. M. Saville states that the bottom and slopes were lined with concrete. The bottom layer of concrete was made of cement, sand and broken stone in proportions of 1:3:6. When this was finished a layer of Portland cement plaster made of 1 part Portland cement and 2 parts sand, with a finishing surface of 4 parts cement to 1 sand, was laid in strips

about 4 feet wide and finished like a granolithic walk. Long strips of coarse wet burlap were used to keep this layer wet and cool, but some cracks appeared. They were thoroughly grouted,



WAINWRIGHT STEEL BOUND CONCRETE CURB AND GUTTER.

and the top layer was then put on. It was laid in alternate blocks. These blocks were 10 feet square for the bottom of the reservoir and 8x10 feet on the slopes. When the first set of blocks had hardened the remaining blocks were laid. These blocks were made the same as the bottom layer except that for the stone in top arch was substituted stone dust and fine broken stone, passing through a 3/8-inch screen, laid before the base of the block had set.

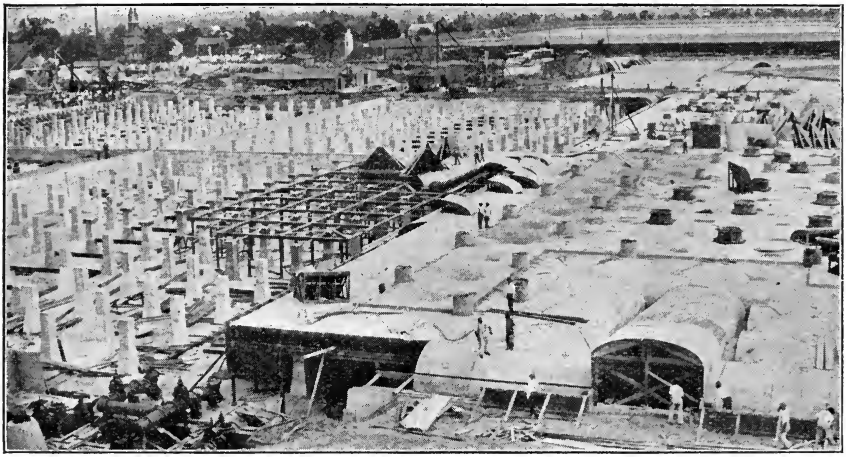
The accompanying illustration shows the method of placing the groined concrete floor and roof of the water filter basins at Philadelphia, Pa.

SUBWAYS, TUNNELS AND SEWERS.

The use of concrete and cement mortar for lining subways and tunnels is rapidly extending. The surface can be made non-absorbent, smooth and light colored where distribution of light is desirable, is quite as durable as stone or brick and usually more pleasing to the eye. By far the most extensive use in this way is in the subways of the New York Rapid Transit Railway. It was used to a large extent in the construction of the Boston subways. Samples of the specifications for concrete for this class of work will be found in the next chapter. The subways in Boston have also been largely constructed of concrete and reinforced concrete.

The Aspen tunnel on the Union Pacific Railway, in exceed-

ingly difficult ground, was lined with 6-inch steel ribs 2 feet apart, surrounded and filled in with concrete. Another inter-



PHILADELPHIA FILTER BED UNDER CONSTRUCTION. CONCRETE FLOOR AND PIERS AT LEFT. CONCRETE GROINED ARCH ROOF AT RIGHT.

esting application of a concrete lining of a tunnel with steel beams in the soffit is found in the Third-street tunnel in Los Angeles, Cal. The special form of specification used will be found in its proper place in the next chapter.

The Musconetcong tunnel on the Lehigh Valley Railroad in New Jersey was lined with concrete without stopping the running of trains. A traveling platform was erected on rails along the side of the tunnel for making the necessary excavations. Following this, forms were erected in 16-foot sections on the face of the completed tunnel and concrete was filled behind them as they were built up until the springing of the arch was reached. Then posts were put in to support the plates on which the steel arch ribs were rested, the centering and lagging was put in place and the concrete deposited for the arch and its filling on each side until the crown was reached, the centering being braced as necessary to keep it from rising at the crown from the load of green concrete on the sides. The arch was laid in 10-foot sections carefully, as the bracing for the centering was very light on account of the necessity of leaving room for passage of cars. Each section was allowed to set

until hard before the next section was begun. Where water was encountered 3-inch iron pipes were placed in the concrete to drain it into the drainage channel of the tunnel.

Concrete has been used for sewers in Europe for many years. In the United States comparatively little use has been made of abandoned it. New York; Boston; Wilmington, Del.; Salt Lake City, Utah; Vancouver, B. C.; Coldwater, Mich., and Chicago railroads have all been users of concrete to some extent and examples are also to be found in Texas and elsewhere. The city of Washington, D. C., has the most elaborate specifications and is at present the largest user of concrete for the larger sizes of sewers. Circumstances dictated a peculiar method of constructing sewers in Coldwater, the invert being a concrete monolith and the arch built of concrete blocks made in a yard at leisure and put in place in the same manner as stone blocks.

The main outlet sewer of the Chicago Transfer and Clearing Yards was built as a monolith, sewers from 36 to 48 inches diameter having 8-inch walls, and those 84 and 90 inches in diameter walls of 12 inches thickness. The invert was laid on a sub-grade carefully made and brought to proper surface by suitable tamping, troweling and smoothing with templets. After the invert had set the center for the arch was put in place. It consisted of circular ribs resting on the invert and supporting 2x4-inch lagging with edges planed to radial lines. Concrete was rammed on this centering and brought to proper thickness by means of templets. This would seem to be a simpler and cheaper construction for the arch than that using concrete blocks.

The list of cities using concrete for sewers is extending rapidly. A few of those using plain and reinforced concrete in addition to those already named are Newark, N. J., Beverly, Mass., Cleveland, O., Indianapolis, Ind., Truro, N. S., Corning, N. Y.

Walter C. Parmley, of Cleveland, O., is the inventor of a system of reinforcing concrete sewers and also of reinforced concrete blocks for building sewers and conduits. The blocks are conveniently made as quarters of the perimeter of the sewer and of any length desired. They have grooves in which rein-

forcing rods can be laid in mortar similar to the reinforcement in the monolithic sewer, around the barrel of the sewer and longitudinally, binding adjacent blocks together.

In the construction of the tunnel of the New York Rapid Transit Railway many sewers must be reconstructed. In a number of instances they have been built of concrete molded in place at a cost about one-third less than brick sewers. Forms were used for making the inverts consisting of strong framework and closely matched planed lagging greased with machine oil. Forms for arches were similar. They were made 12 feet long. The concrete was first put in place and brought within ½ inch of the grade, a template being used as a guide. The form was then accurately set in position and the remaining space filled with 1 to 1 Portland cement mortar. The form was then braced by struts to the sheeting of the trench and vertical planks set for the outside of the spandrel wall. Concrete was then carefully rammed in and made smooth. After 24 hours or more the form was withdrawn and a thin cement grout brushed over the surface. Concrete was in proportions of 1:2:4, Portland cement, sand and broken stone 1 inch and less. When arch centers were put in place the lagging was first plastered with 1 inch of 1 to 1 mortar, and concrete was then rammed in to a depth of 8 inches. Side forms on slope kept the side concrete in place and the crown was formed by hand. Some sewers had concrete invert and brick arch.

The borough of Brooklyn, New York, formerly used cement pipe in sewers. This practice seems to have been discontinued, but the sewer department is now using concrete very extensively in constructing large storm water and outlet sewers in open cut and tunnel. Concrete lends itself most readily to the peculiar constructions necessary at junctions, overflows, connections with intercepters, and the like, and, with reinforcement where most needed, is more readily put in place, carries the loads with more satisfaction and reduces the cost. It would be necessary to devote a large part of the book to this system if an attempt were made to show the many interesting features of the designs and methods of construction.

WATER AND SEWER PIPE.

Cement mortar has been used with more or less success as a

lining for light steel or iron pipes, the cement preserving the steel from corrosion and keeping the pipe constantly of the same area of cross section. Owing to errors when making connections, and other similar reasons, this construction has never been very popular and it is now seldom used.

Cement pipe reinforced with wire cloth, expanded metal or

CEMENT SEWER PIPE.

steel rods, according to the size, strength required and system of reinforcement adopted, are made for carrying water under pressure. These pipes are sometimes made in place and sometimes made in sections and laid and jointed as other pipes are placed.

Sewer pipes are made in molds, the concrete being tamped by hand or compressed by hydraulic or other power. Occasionally they are reinforced with steel, but ordinarily they are given sufficient thickness so that concrete alone is required. The pipes are laid in the same way as other sewer pipes.

PIERS, BREAKWATERS, DAMS, LOCKS AND OTHER MASSIVE MONOLITHIC CONCRETE STRUCTURES.

Bridge piers are frequently constructed with a heart of cement concrete and in rapidly increasing numbers are constructed entirely of such material, the exterior receiving a coating of Portland cement mortar specially prepared with the best of materials. One recently constructed in Tennessee is entirely of concrete made with 1 part Portland cement, 3 parts sharp sand and 5 parts broken stone to pass through a 2-inch ring, and is 63 feet high, 24 feet wide under the coping, 8 feet thick,

with a batter of ½ inch to the foot. This is the highest concrete pier in this country.

The conservative railway managers are rapidly extending the use of cement and concrete for all railway structures, and it is not impossible that within a comparatively short term of years nearly all structures from pipe culverts to station buildings on some railroads will be at least externally of concrete.

There are several notable examples of the use of monolithic concrete for such structures as the walls of canal locks, and some instances of the use of blocks made of concrete and set in place after completion.

In the construction of piers and breakwaters cement has been used very largely in recent years. Very large blocks of concrete stone are built, sometimes in place and occasionally elsewhere, and then laid in place as natural stone blocks would be. Heart walls and filling may then be constructed of concrete laid in place. Some specifications for this class of work follow in the next chapter.

The dam of the Lynchburg, Va., water works is of the gravity type. Its crest is 415 feet long, of which 150 feet is a spillway. The maximum height above bottom of foundation of the main dam is 66 feet and maximum bottom width 39.25 feet. The maximum section of the spillway has about the same height above the foundation and a bottom width of 44.25 feet. The down stream face is stepped. The crest of the spillway is 10.5 feet above the top of the dam. The masonry is of concrete blocks in which large stones are imbedded. The blocks are rectangular and irregularly shaped on such designs as insure thorough bedding. The outside blocks are made with Portland cement, and those within with natural hydraulic cement. The wing walls each side of the spillway, the gate chamber wall and the parapets are reinforced with square twisted steel rods. The down stream edge of the spillway crest is of cut stone and the treads of the spillway steps are of granite blocks. See next chapter for specifications for blocks.

A solid concrete dam has been built across the Maquoketa river at Manchester, Iowa. It is 185 feet long, about 101 feet being from 9 to 11 feet high and the remainder 1.5 to 9 feet. The back of the dam is vertical except for a batter of 1 in 10

where the sluice gates are located. The top of the dam is 3 feet wide and has a 10 by 10 inch pine timber bolted on the crest and a 6 by 6 inch on the rear of the top, with 2-inch planking between to take the shock of floating ice. A flash-board 2 feet high can be raised on the outer timber. The base is 9 feet wide and the face is a reversed curve. The concrete is of 5 parts good gravel to one part Portland cement, this proportion being slightly more than enough to fill the voids. Although there was no plastering of rich mortar on the back of the dam, it is tight. The faces of the dam were tamped with oblique tampers and are smooth and dense. Cement cost $1.50 a barrel and gravel 50 cents a cubic yard, and the contractor's bid on labor, forms, etc., was $2.50 a cubic yard of concrete. The volume of the dam was 260 cubic yards, and it required 280 loads of gravel and 350 barrels of cement, and was built in 15 days.

A concrete sea-wall at Scarborough, England, which has taken seven years to build, has recently been completed. It is built of about 1,500 concrete blocks weighing 2 to 9 tons each. Its length is 4,200 feet, height 40 feet, width at foundation 30 feet, and at top 10 feet.

Wm. Watts, an English engineer, recommends concrete instead of clay puddle for an impervious core to an embankment or earth dam, more especially in the trench made in the foundation of a dam, which is sometimes required to carry the core down to an impervious stratum, so that there will be no leakage under the dam. He prefers clay puddle for the core of the embankment above.

At Barossa, South Australia, is an arched concrete dam 472 feet long on the top, with a radius of 200 feet, a height of 95 feet above the ground line, 4.5 feet thick at the top and 34 feet at the ground line. It is built of concrete with about 5 cubic yards of granite boulders placed by hand not less than 6 inches apart in every 30 cubic yards of concrete, and about 40 tons of old rails in the upper 15 feet of the dam where it is too thin to warrant placing the boulders. Observation of extremes of 50 degrees in temperature on 6 different days showed an expansion of the length of the top of the dam of about 1.5 inches and a motion of the crown up stream of ⅞ inch.

The new Walden Pond dam of the Lynn, Mass., water works

is of earth with a concrete core wall. Below the base of the wall sheet piling was driven to hard material, about 18 feet down. The foundation of the concrete core wall was begun 3 to 6 feet below the top of this piling, the top of the piling being 19 feet below the original ground surface and 70 feet below the top of the dam, or 67 feet below the top of the concrete. The foundation is 9.5 feet thick and reduces to 8 feet before the ground surface is reached and to 4.66 feet at the top. Concrete was mostly 1 part Portland cement, 2 parts sand and 5 parts gravel, mixed with Dromedary mixers, gravity mixers and by hand. About 20 per cent. of the wall is composed of boulders up to 2 cubic yards volume, bedded in the concrete. The front face is plastered with 1 to 1 mortar. The earth filling was deposited in layers and puddled or rolled. The entire dam will be 2,200 feet long, 200 feet wide at the base and 52 feet at the crest. The pond being filled by pumping, there is no spillway.

BUILDINGS AND PARTS OF BUILDINGS.

Every city now has examples of houses, stores, factories and other buildings constructed wholly or in part of concrete. Foundations, walls, floors, roofs, partitions are all in use and may be made solid or hollow, monolithic or of blocks, of plain concrete or reinforced with various forms of steel. Descriptions of a few to indicate the various materials and methods of construction are given. Where the descriptions partake of the nature of specifications they are given in the following chapter.

Many handsome buildings have recently been constructed in Florida of a concrete made of Portland cement and coquina shells from the vast deposits of that material on the seacoast of that State.

Some Northern Pacific railway stations are notable examples of concrete construction. In one case the walls are hollow, two walls each 5 inches thick, and an 8-inch space between, with 4-inch cross walls every 2 feet. Tower walls are solid and 18 inches thick. The foundations were made of broken stone or gravel concrete in proportions of 1:3:5. The walls were made of gravel concrete in proportions of 1:2:5, with a facing 2 inches thick made of 1 part cement, 1 part sand and 3 parts marble chips. The walls were laid up inside the forms in layers 10

inches thick, and before the cement was too hard the entire outside surface was brushed over with a steel brush, making the surface rough and exposing the marble chips.

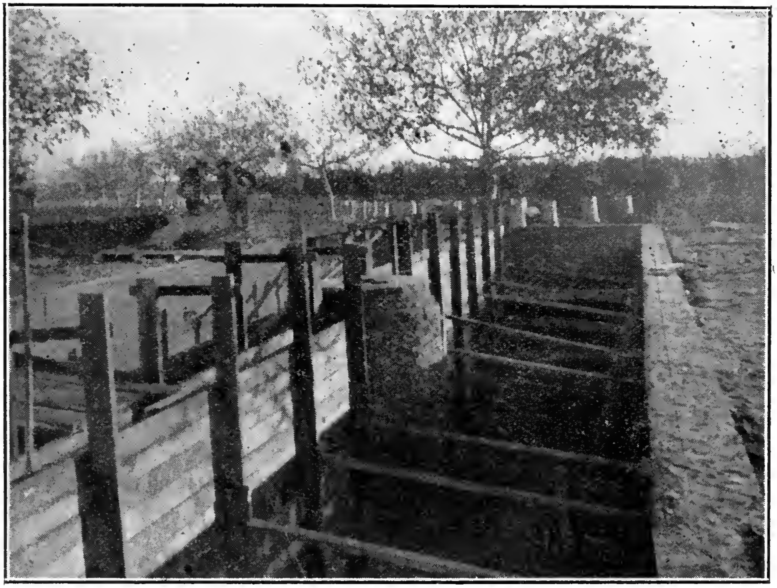
The shops and roundhouse of the Central Railroad of New Jersey at Elizabethport have recently been built of concrete with steel reinforcement, where desired, from foundation to roof, both inclusive.

Many factory buildings are built like the mills of the Lehigh

CONCRETE SHELTER HOUSE, RIVERSIDE PARK, INDIANAPOLIS, IND.

Portland Cement Company. The proportions for the concrete in this case were 1 part Portland cement, 4 parts sand, 8 parts crushed stone and 2½ parts rough stone, one barrel of cement making 1.35 cubic yards of concrete. As the concrete was deposited the rough building stones, weighing from 30 to 50 pounds, were bedded in it, the concrete being well rammed about them. A cubic yard of the concrete was found to consist of 295 pounds of cement, 880 pounds of sand, 2,400 pounds of crushed stone and 700 pounds of rough building stone. The walls were left rough as they came from the forms, except about the windows, which were finished off with cement and sand. The walls can be smoothed somewhat by applying with a whitewash brush a coat composed of cement and lime. A much better finish can be given by plastering the surface with

a mortar of 1 part Portland cement and 3 parts fine, sharp sand, using a mason's wooden trowel. The thickness of the walls varies with the height. One 45 feet high is 17 inches thick for the first 30 feet and 12 inches for the remainder. Those 16 to 25 feet high are 10 to 12 inches in thickness. The forms for placing the concrete were made of 1½-inch boards held in place by a framing built up of scantling 3 inches wide by 6 inches and 3 inches by 8 inches, and 1½-inch boards. The frames for



FORMS FOR BUILDING SOLID CONCRETE WALLS.

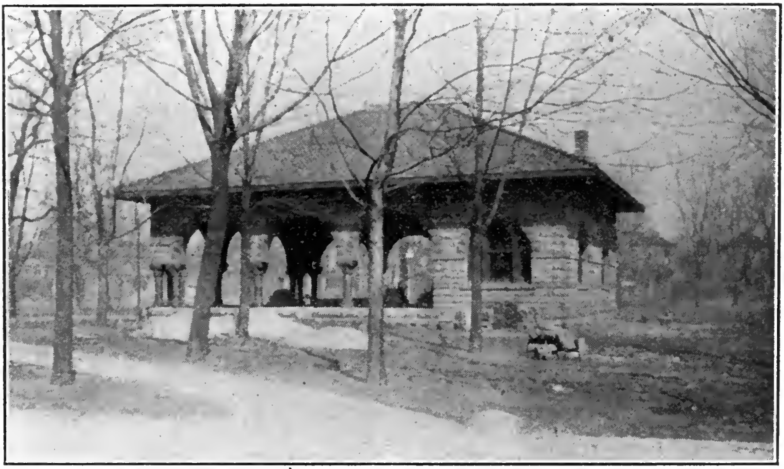
the two sides of the wall are built up together and bolted together through the uprights, and the concrete is filled in as the framework rises. When the concrete work is done the frames are taken down, the bolts are removed and the holes filled with cement mortar.

The walls of the power house of the Virginia Electric Railway and Development Company at Richmond, Va., were built of massive concrete blocks molded in boxes, where they were allowed to remain until set. They were lifted by means of irons running through them and bearing on thin iron strips imbedded in the bottom, as they were moved before full strength

was developed. Such special forms as cornices, window courses, etc., were molded separately for architectural effect.

In foundation walls it is well to insert wooden pins of proper size where water, gas and sewer pipes are expected to enter, as the concrete is very difficult to cut.

Portland cement tiles for floors, bases of walls, and special uses have been made for a number of years. Colors are readily used as desired, and no heat being necessary, form and color may be as exact as is desired. Roofing tile of Portland cement



SHELTER HOUSE OF HOLLOW CONCRETE BLOCKS, MILITARY PARK, INDIANAPOLIS, IND.

are also very successful. They are light, durable, fire-proof, not breaking on contact with water when white-hot, and frost-proof. They are compressed under very heavy pressure and can be made of any desired shape or color.

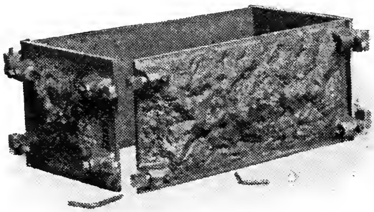
CONCRETE BLOCKS AND MACHINES FOR MAKING THEM.

One of the most rapid growths in the cement trade has been that of the use of concrete blocks. Although Mr. H. S. Palmer had been at work upon the development of the first practical machine for making hollow concrete blocks for some ten or twelve years prior to 1902, there was no pronounced effort to extend the use of the machine until January of that year. In but little more than three years the industry has grown until

the number of patents on machines and blocks now approximates one hundred, and there are probably 2,000 manufacturers of the blocks more or less actively engaged.

There are two principal methods of making the blocks, the dry and the wet. By the dry method the materials are mixed with the smallest practicable amount of water and are thoroughly tamped into the molds. The blocks are made on pallets on which they can be carried away from the mold or machine as quickly as they have been formed, thus leaving the machine ready to make another block. It is therefore possible to make blocks by this process as rapidly as the sides of the machine can be put in place, the mortar mixture tamped into it, the mold opened and the block on its pallet removed. The expense for apparatus is thus reduced to a minimum and the speed of operation is limited only by the number and expertness of the operators, the facility with which the machine can be handled and the convenience of the plant for handling the raw materials and the finished product.

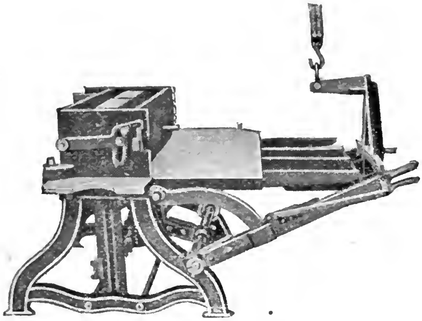
The simplest machines are merely molds with removable sides, ends and cores, and there are many methods of combining



A SIMPLE BLOCK MOLD.

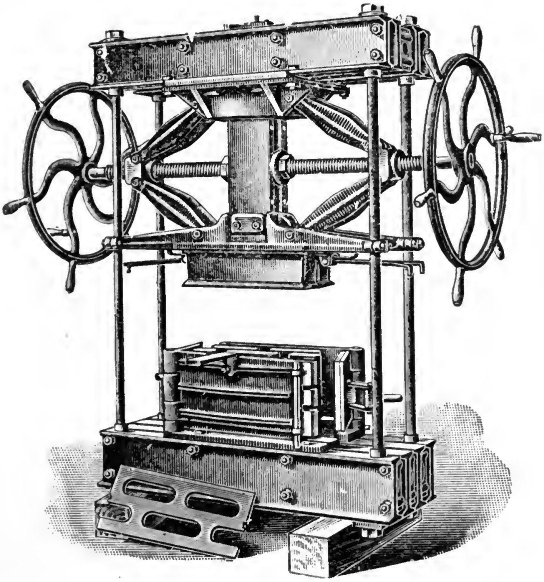
and operating these elements. In some cases the machine or mold is moved away from the block, rather than removing the block from the machine. Other machines have mechanical devices for raising and lowering cores and blocks, for operating the removable sides and ends of the mold, for lifting and transporting the blocks, etc. This gives opportunity for the application of much inventive genius and the variety of machines is added to at least monthly. The tamping may be done by hand or by mechanical tampers, of which there are several designs on the market, handled in various ways. A few machines apply

pressure to the blocks instead of the tamper, some by means of levers operated by hand or by machine, others in hydraulic presses.



A BLOCK MACHINE WITH CORES REMOVED BY LEVER AND FORK FOR COMPLETED BLOCKS.

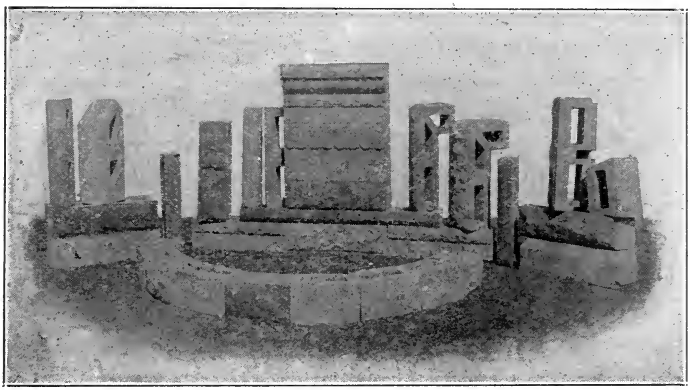
Some of the molds are fixed in size, fractional blocks being made by inserting plate partitions, and a different mold being required for each size or shape of full-sized block. Others have



A MACHINE FOR MAKING PRESSED BLOCKS.

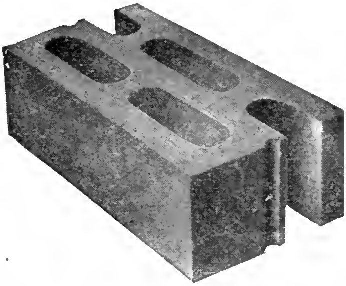
adjustable beds on which various sizes and designs of side and end plates and cores can be operated. Others are adjustable in

all dimensions with the help of some extra plates. The forms and sizes of blocks are endless in their variety, each inventor having his own ideas of the best form and size of block. Some have worked out in detail all possible forms of blocks for



VARIOUS FORMS OF TAMPED HOLLOW CONCRETE BLOCK.

straight walls, pilasters, corners, bay windows, chimneys, chimney breasts, window and door caps, sills and sides, string courses, water tables, cornices, etc., and are prepared to furnish anything which may be needed for any sort of building. There is but little uniformity in the blocks on the market, and

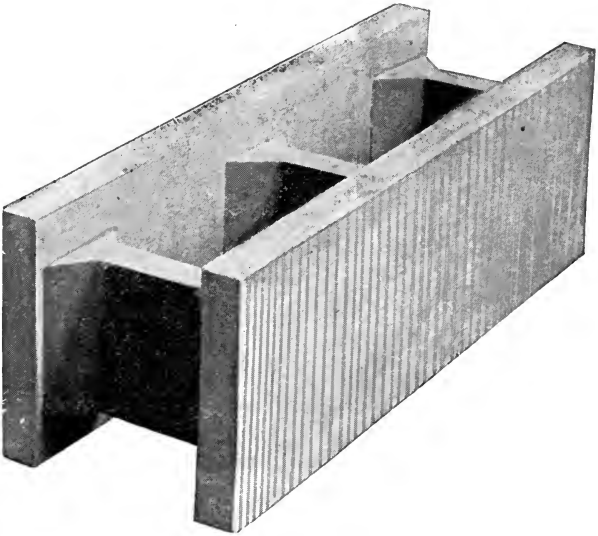


ONE FORM OF PRESSED HOLLOW CONCRETE BLOCK.

in fact in some instances there seems to have been an effort to make blocks which cannot be used with those made on any other machine.

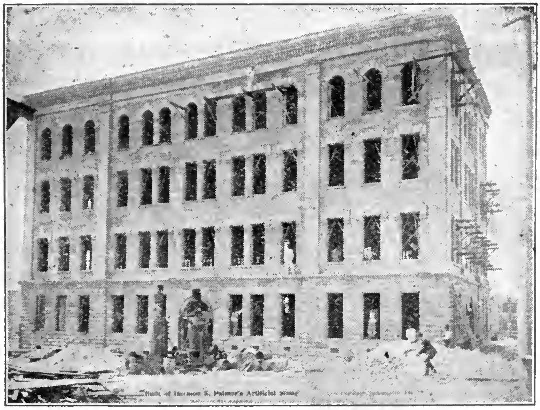
By the wet method the blocks are cast in molds, in which they must remain for some hours or days until they have set, while the blocks made by the dry process can be removed on

pallets as soon as formed. Molds are made of wood, iron or steel, or in some systems of sand. The molds with solid sides can be used indefinitely, a number being required sufficient to



A CAST STONE BLOCK.

keep the working force busy until the cement has set and the molds can be removed to use again. Sand cores are sometimes



AN OFFICE BUILDING OF HOLLOW CONCRETE BLOCKS.

used to take up some of the excess of water in the concrete and hasten the time of setting. According to two or three systems

sand molds are used, partly to give a special texture to the surface, partly to regulate the amount of water automatically to the requirements of the cement in crystallizing, and in one instance, it is claimed, to apply a chemical for hastening the hardening of the surface.

This is not the place to make suggestions regarding the operation of cement block plants, but it may be well to make some suggestions regarding the materials and methods of manufacture of blocks.

A concrete block wall should be as nearly waterproof as possible. Stone or brick masonry walls absorb water from the atmosphere, and it is necessary to use studding and lath, or devices producing the same results in order to preserve plastering. The ordinary concrete block made by the dry process is of the same porous nature. If the plastering is to be put directly upon the inner surface of the concrete block wall, the passage of water through the block must be prevented. The hollows in the ordinary concrete block are there to save concrete and to save weight of block, the thickness of wall required for lateral stability being greater than is necessary for carrying the weight on the wall, if made solid. Some have assumed that these hollows would make the wall waterproof, but it has been learned from experience that the moisture passes through the remaining concrete and reaches the inner surface of the wall unless other precautions are taken. One form of block has two rows of hollow spaces, staggered, so that moisture must follow a tortuous course in reaching the inner surface. Several manufacturers make blocks in two pieces, which together make a hollow wall, the two tiers of blocks being bonded together in various ways, and the passage of water through the wall being prevented by the lack of continuity of block through the joint, even, it is claimed, if the joint is made with a dense cement mortar which holds the blocks firmly together. There are several preparations for making blocks waterproof which are described under the head of "Waterproofing Concrete." One very important adjunct to all these methods of keeping water out of a wall is the density of the block itself. This should be the first consideration in determining the proportions of materials to be used in making blocks, and it is in reality given

no thought whatever by the average block maker. It is possible to make concrete waterproof by using the proper proportions of cement, sand and gravel and working the mixture with the proper amount of water and with the proper attention to the finishing of the outside surface, as elsewhere described in this chapter. It is not commercially practicable to take this care of the surface of a hollow block nor to use the full amount of water desirable in blocks made by the dry process, so that approximation to water tightness is all that can be made. The most satisfactory mixture of gravel or broken stone, sand and cement must be determined by experiment with the materials to be used, according to the principles stated elsewhere in this book.

Faces of blocks must be of pleasing designs, architecturally correct. They must be well finished, by using proper molds, by tamping faces thoroughly, using better materials for the face if the best appearance is to be secured at lowest cost, and by carefully removing molds, and handling blocks so that faces and edges shall show no marks of cement sticking to molds or of careless marring. Crazing or hair cracks appear on faces sometimes because blocks are subjected to changes in temperature before the surfaces are fully cured, and sometimes because there is an excess of cement on the surface. Brushing of the surface at the exact stage of hardening which is best will improve the faces in this regard. Experiment is necessary to learn the exact time for the conditions of temperature, setting time of cement, amount of moisture, etc.

Each machine has its own method of operation and its own best kind of mixture, so that only general directions can be given here. The materials, when the best proportions have been determined, must be mixed thoroughly. The small plant can not afford a power mixer, and must take all the more pains. Too much must not be prepared at a time, so that partial set takes place in the pile while standing, thus weakening the block, and especially preventing thorough consolidation.

Blocks must be made on a hard floor, that no dirt may get into the concrete, and the floor must be kept clean that no lumps of partially or wholly hardened concrete may get into the concrete and prevent consolidation of the block. Molds

and tools must be kept perfectly clean and should be wiped frequently with an oiled cloth to keep them smooth and prevent sticking, care being taken not to discolor the face of a block by using too much or too dirty oil.

Blocks are very often injured by jars in handling, especially in taking out of the machine and in setting in rack, also on cars running on a rough track. The blocks must be stored for the first few days where the changes in temperature will be as slight as possible, and should be protected from the direct rays of the sun. At the same time they must be so stored that they can be sprinkled thoroughly without danger of injury to the faces. Blocks are often rushed into the wall too quickly and careless handling mars their appearance. There are several preparations on the market for hardening blocks quickly, whose composition and mode of action should be fully known before they are used in important work. If the substance acts by setting up a favorable chemical action and crystallization ical which ultimately produces a disintegration of the cementing substances in the concrete, the ability to handle blocks and hastening it, there can be no objection, provided there is not a future reaction; but if this action is produced by a chem- quickly is gained at too great a cost of reduction in durability. Some of these substances also contain matters which are soluble in water and produce efflorescence and discoloration.

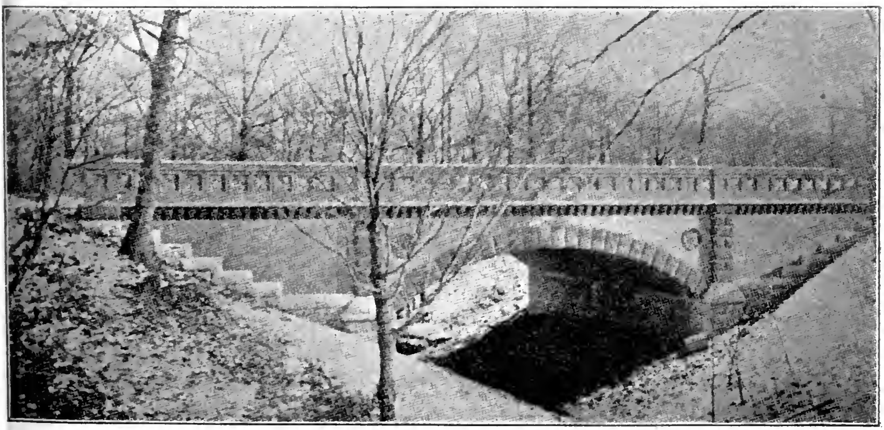
ARCHES.

Many arches have been constructed of concrete without any steel reinforcement. One at Westvale, Mass., has a span of 66 feet and a clear roadway of 35 feet. The arch is a semi-ellipse, with a rise of 11 feet. The foundations of the abutments rest on firm gravel and sand, the concrete composing them being made of sand and gravel from the vicinity in proportions of 1:3:6. The gravel ranged in size up to 4 inches. The center was built of old material from the replaced bridge and the lagging was 2-inch planed spruce plank matched and put together closely. The arch concrete was made with gravel of 2 inches diameter and less in proportions of 1:2:4, hand mixed. Failures to make a smooth surface next to the lagging were remedied in the hardened concrete by cutting out pockets, setting in half-inch bolts with nuts on for anchors and filling the

pockets with concrete to a smooth and regular surface. After everything had set the entire face of spandrel walls and arch ring was dressed to line by stone chisels, which gives a fairly good appearance.

A concrete arch of 14 feet at Piqua, O., was constructed on a center formed of earth filled into the opening between the completed abutments so that its upper surface was the form of the soffit of the arch. The concrete was filled in on a layer of 1-inch boards and tar paper, wooden forms on the sides giving the side walls. A 3-inch layer of 1 Portland cement, 2 fine crushed stone and 5 coarse broken stone was spread first, then 6 square iron rods of 1 inch cross section were laid on from one abutment to the other, being 3 feet apart. The concrete was then filled in to give an arch 16 inches thick at the springing line and 10 inches at the crown, and side walls 10 inches thick. The facing of the walls, laid at the same time, was made of 1 part of cement and 2 parts of stone dust and was 1 inch thick.

Quite an elaborate arch bridge of two spans was built by the Central Railroad of New Jersey at Northampton, Pa., using sheets of expanded metal laid in radial lines similar to the radial joints in a stone arch and four joints of the same sort made with sheets of paper, two on each side of



A CONCRETE ARCH.

the crown, running entirely through the arch masonry. The molds were built of 2-inch plank planed on one side and nailed to 3x5-inch and 4x6-inch studding on 3 to 3½-foot centers. The braces were made of 2x9, 4x6 and 6x6-inch stuff. Proportions of cement were 1 cement, 3 sand, 6 slag from ⅜-inch to 2½-inch screen in foundations; 1:3:7 in wings; 1 cement, 2 sand, 4½ to 5 broken stone, from ¼ to 2½ inches in arch ring and parapet; and 1 cement, 1½ to 2 sand in facing. All cement was Portland cement made in the neighborhood.

The concrete viaduct of the San Pedro, Los Angeles and Salt Lake railroad near Riverside, Cal., is a notable example of plain concrete work. Its total length is 984 feet, width 17 feet, and average height 55 feet. There are eight main arches, each of about 87 feet span and 37 feet rise; piers are 16 by 28 feet at the footings; approaches are double retaining walls connected with the abutment by an arch of 38.5 feet span. Local cement and washed bank gravel in proportions of 1 to 11 were used in foundations, piers and spandrel walls. Foreign cement, sand and crushed rock were used in the arch rings in proportions of 1, 2 and 4.5. "Standard" (California) Portland cement was used in coping and parapet walls. There is probably but one longer concrete viaduct, the Glenfinnen in Scotland, which is 1,248 feet long.

On the St. Louis and San Francisco railway concrete bridges without reinforcement have been built at Lindenwood and Cheltenham, Mo., and elsewhere on the theory that under the conditions on this road a saving of 50 per cent. in concrete is necessary to warrant the use of reinforcement and this can not be done under the existing conditions. The concrete in the bridges referred to cost $4.60 and $4.80 a cubic yard, respectively, in place.

MISCELLANEOUS USES.

The street railway company in Minneapolis, Minn., made a novel use of concrete in reconstructing some of its lines and making the rails continuous by welding the joints. A longitudinal beam of concrete was constructed, to which the rails were spiked before the cement was set, thus making a continuous support to the rails, and a tight fastening for them.

Concrete is frequently used as a foundation for the wooden ties of street railroads, but in this case the ties are displaced entirely. The usual concrete foundation for an asphalt street was laid over the street, and the pavement completed by laying the asphalt. Constructions of slightly different designs have been adopted with greater or less success in other cities, for example, Scranton, Pa., and Indianapolis, Ind.

Within the past ten years there have been several instances of making solid foundations in gravel and sand, especially if under water, by injecting a thin cement grout by means of tubes run down to the stratum which it is desired to solidify. Open gravel can be very successfully treated in this way. Fine sand will refuse the grout if already filled with water.

For such small uses as cistern tops, horse blocks, steps, caps and sills, plastering cisterns, basins and manholes, Portland cement is the best material. Specifications for sidewalk mixtures are applicable to most of these uses, with slight modifications.

Tiles made of 100 parts by weight of damp sawdust, 240 parts Portland cement and 48 parts water can be nailed without cracking. The sifted sawdust should be thoroughly wet and allowed to stand 24 hours before mixing and the tiles should be frequently sprinkled while setting for successful results.

Concrete coal bunkers with concrete chutes are used at the Dumferline Power station, Scotland.

Fences and ornamental gateways in cement concrete are very successful.

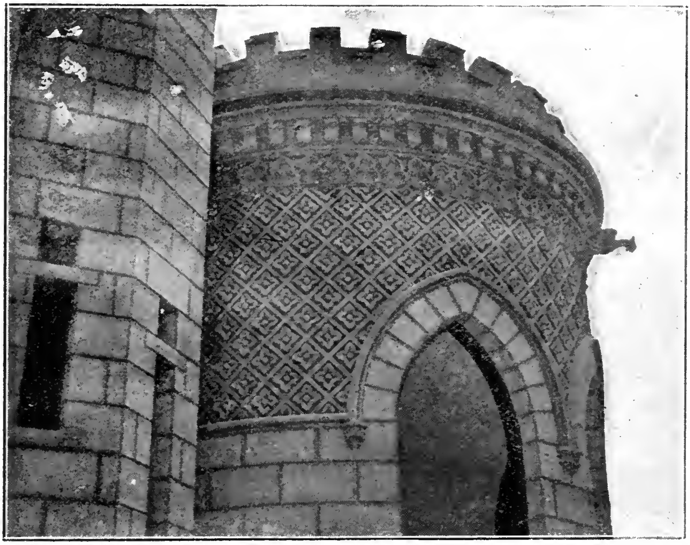
Cement can be used for statuary, fountains, monuments, where the color is satisfactory, and is frequently very effective.

Concrete, without any reinforcement, was used as long ago as 1860 in Germany for a factory chimney about 160 feet high.

There are several forms of burial caskets in concrete, monolithic and in slabs which fit together so as to be locked and water-tight. One French form uses steel rods as reinforcement.

The ornamental work for buildings is very easily and cheaply made of concrete. Care is needed to make good mixtures especially for the faces and to cure the blocks thoroughly and

under uniform conditions of temperature and moisture that there may be no crazing or hair cracks. One contractor reports excellent results using one part of Portland cement and six parts of gravel for the body of the block and one part of Portland cement of exceptionally uniform color to two parts of ground Bedford stone chips for the face, at cost about one-



ORNAMENTAL CEMENT WORK ON A CUBAN RESIDENCE

half that of stone for plain work and about one-quarter for molded work. Porch piers, columns, and caps, newel posts, balustrades, vases, seats, fences, horse blocks, hitching posts, fountains, including elaborate designs of molded work and figures make a list illustrative of the many ornamental and useful objects which can be constructed of concrete.

The cements required are usually those of lightest color, and in some works it is necessary that they be non-staining. Uniformity of color is most essential.

For the faces of stones fine white sand is usually demanded. One good mixture is 1 part cement to 1½ parts ground Bedford chips and ½ part of fine white sand. An excellent granite face is given by hard crushed granite (such as granite boulders), of pea size and smaller.

The molds should be somewhat porous to absorb any excess of water in the mortar. Wooden molds are good if the patterns are not too delicate and the surface need not be too fine. Iron

CONCRETE FACING AND ORNAMENTAL WORK ON GERMAN RESIDENCES.

molds are not sufficiently porous. Plaster molds are excellent, but require expert men to mold the patterns in clay. This class of work is best made with wet mixture, and the porous mold prevents the formation of air holes on the surface and

trouble with excess of water when curing. The stones are also less porous when finally set. The wet processes of making concrete blocks and artificial stone in sand molds, elsewhere described, are applicable. Trowel finish on artificial stone is not usually advisable. It brings neat cement to the surface and hair cracks are almost certain to appear, even under the most careful manipulation in curing.

The Greek amphitheatre at the University of California, is built of concrete, three-fourths in excavation and one-fourth above the original ground surface. A central circle 50 feet 8 inches in diameter has about it on one semi-circle in order, a tier of 12 steps 3 feet broad and 5 inches rise, a 9-foot aisle, a wall 5 feet high and 10 inches thick with a bench on its front, and 19 rows of steps with 30-inch tread and 18-inch rise forming seats, with radial aisles, having steps of 15-inch tread and 9-inch rise, and a wall 2 feet high and 10 inches thick. On the other side of the central circle is an 18-foot walk from the side entrances sloping down from the base of the seats to the central circle; the stage, 134 feet long, about 50 feet wide and about 5 feet above the central circle; and the wall with its classic ornamentation and end pylons, molded in place, surrounding the stage on three sides. All is of concrete, some steel reinforcement being used where it was appropriate, with the exception of the central circle, which is of disintegrated granite on a foot of loose rock, well underdrained. The effects of contraction of of concrete and local settlements are concentrated by No. 30 sheet steel plates placed vertically in the steps every 8 or 10 feet, and in the panels of the wall back of the stage. This construction has prevented any temperature or settlement cracks.

METHODS OF REINFORCING CONCRETE.

There has been a very rapid development in the use of reinforcement for concrete in structures in this country since the last edition of this book was published. The study of the action of such structures has proceeded with great thoroughness and some approach has been made toward the formulation of methods of computation of strength and dimensions of structures of various sorts, with strong indications that formulae will shortly become as definite as those for steel construction, pro-

vided methods of construction can be given similar uniformity. It is not the purpose of this book to give methods of calculation and design, but simply to give some description of the various systems which have been proven to have considerable value and some examples of actual construction. The various systems and modifications of systems which have received names are aranged in alphabetical order. Following them are mentioned other methodsof using reinforcementwhich have not received specific names and structures containing one or more of the systems are described. It will be noted that many of the systems differ very slightly, often only in the details of connections of rods or bars, and that there are many designs in use which have never received specific names.

In the Ambrosius system the principal reinforcing bars have projections to carry a wire cloth which furnishes the necessary transverse tensile strength.

The Armored Concrete Construction Company (English) construct piles with angle irons in corners, connected by straps at intervals and wire spring diaphragms alternating

The Bone reinforcement for walls, especially retaining walls, consists of steel bents of angles and plates embedded in the back part of the wall at fixed distances apart and tied back into the greatly widened foundation of the wall by angle irons with brackets attached to prevent pulling them out of the concrete. A similar anchor extends toward the front of the wall when deemed necessary. The ends of these anchors are connected by an angle bar running the length of the wall and the bottoms of the bents are connected together by an angle bar. Mr. Bone recently made a comparison of bids for a plain concrete wall for the same locality and the same work, showing that the plain concrete wall woulld cost $21.20 a linear foot as compared with a cost of $13 for a reinforced concrete wall.

The Bonna (French) system uses steel cross-shaped sections for reinforcement, the relative strength of one arm of the cross having considerable variation for various situations. It is specially used in making pipes, the reinforcement being arranged with a number of longitudinal bars and a spiral encircling them, the longitudinal bars being notched to receive the spirals. The Columbian fire-proofing system uses a double cross section devised by Bonna.

The Bordenave (French) system uses small steel I-beams and round rods. It has been used in floors, reservoir coverings and pipes, the bars being tied with wires at their intersections. For pipes machinery is used for winding the helical rod around the longitudinals (placed outside if the pressure is from the outside) and the coil is then drawn out along the pipe to the spacing desired.

The Boussiron and Garric (French) system consists of series of rods on the tension lines in the concrete, and on diagonals in deep beams. Floor slabs have two sets of rods at right angles. Columns have vertical rods tied together with hoops of flat bars. The system is also used in circular tanks above ground.

The Bramigk (German) system for floors uses bars near the lower surface and concrete or earthenware pipes parallel with them about which the concrete is laid, thus making a hollow floor with the steel reinforcement in one direction on the tension side.

The Buckeye floor construction consists of steel floor beams and joists supporting continuous corrugated iron plate arches of a few inches span with concrete filling above.

The Busso system is similar to the Boussiron in principle.

The Chassin system is similar in principle to the Boussiron.

The Chaudy (French) system has two sets of longitudinal bars near top and bottom of beam, which are rigidly connected by rods, closed hoops, or flat bars riveted to them. A series of beams laid close together, but monolithic as to laying of concrete, forms a floor. Walls, stairways, tanks and aqueducts are also constructed in this system. It also uses transverse rods bent in rectangles about the longitudinal rods, which are near the lower surface, the loops or waves thus formed extending along the upper surface of the slab until they reach the next longitudinal rod when they are bent back to enclose it.

A similar system of the "Societe des Chaux et Ciments de Creches" (French) uses a small rod at the top of a beam to keep in place the rods used for connecting the lower rod in the beam and the floor slabs on the top of the beam.

The Chicago system of Theo. Kandeler uses steel floor joists and transverse channels supporting sheet iron arches on which

concrete is deposited, steel bars embedded in the concrete supporting wooden strips, also embedded, which in turn carry the wooden floor. The Roebling ceiling is attached to the bottom of the floor joists.

The Clinton Wire Cloth Company supplies a wire fabric which has the intersecting wires welded together by electricity and is used for all purposes for which wire cloth or intersecting rods are adapted.

The Coignet (French) system in floors uses two sets of rods at right angles near the lower surface with sometimes a similar system of lighter rods near the upper surface, the two systems being connected with stirrups. Beams have rods near top and bottom of section connected with stirrups or a rod running between the upper and lower rod in zigzag and tied to these rods at the points of contact with them, thus forming a sort of triangular system of girder bracing. Columns, foundations, walls, retaining walls, stairways, pipes, elevated tanks, etc., are made with modifications of the system. This was the eariest system suggested, 1888, but was not put in practice so early as some others. For pipes hoops are made with the ends hooked together, a rod passing through all the hooks to hold them together. The longitudinal rods are tied occasionally to the hoops, and additional diagonal rods or wires are used when deemed necessary.

The Columbian fireproofiing system uses rolled beams embedded in concrete with Bonna double cross sections as reinforcement for floor slabs, also embedded in the concrete and attached to the top flanges of the floor beams by flat iron stirrups over the flange and slotted to receive the ends of the cross bars. The bottom flanges of the beams are covered with concrete held in place by hoop iron clips hanging from the lower flanges.

Considere (French) has developed a number of applications of reinforcement and the system of hooped columns of concrete may properly be given his name, though it is used in one form or another in several systems.

The Cottancin (French) system was patented in 1889. It uses a woven net work which does not require fastening of the wires or bars together at their intersections. Floor slabs are

supported often enough to be thin and the net work is embedded near the center. The stiffeners are vertical slabs of similar construction with the webs interwoven with that of the horizontal floor slab by means of the projecting ends of the wires of the stiffener. Thin partition walls, roofs, domes, pipes, rectangular and circular tanks are also constructed according to this system.

The Coularou (French) system uses rods near the lower edge of beam and also rods running from ends toward center of span near top, bending down on 45 degree diagonal to bottom near center of span, with diagonals connecting the two series of rods. Floors, columns, roofs and walls differ only in details from the preceding system.

The Cummings system uses bars of varying lengths bent near ends to diagonal for resisting shear and looped at ends.

The Czarnikow system does not connect the reinforcing flat bars with each other except by means of the embedding concrete.

The Degon (French) system has two sets of rods near top and bottom of beam connected by wire wound round and also projecting up between in the general form of a letter W closed by extending each wire across the top. They may then be extended through the intervening floor slab to the next beam. The floor slabs have these rods near the lower surface connected by transverse wires of sinuous form embedded in the concrete, and without the longitudinal rods near the upper surface. Reinforcement of walls and posts is modified in position to conform to the change in lines of stress but follows the same system of closely connecting all the lines of reinforcing together, so that they are capable of considerable resistance to the stresses without the aid of the concrete. For pipes bent rods of form above described are used for the circular reinforcement and the longitudinal rods are placed in the outer bends and tied there.

The DeMan bars for reinforcing are rolled in wave-like form. The bars are square in cross section increasing and decreasing in dimensions with the undulations.

The Demay (French) system uses flat bars very thoroughly connected together by interlacing bars of smaller cross section.

Columns are reinforced with round bars which are partly interlaced with the bars in the beams above and below them and partly carried to the columns above and below.

The Donath (German) system uses steel floor joists with small T-bars transversely, which are tied together by hoop iron perpendiculars and diagonals, bolted to the T-bars. S-shaped bars are a special form peculiar to this system. The space between beams is then filled with concrete, a wire netting below carrying the ceiling of the room below. Molded blocks fitting the S-shaped bars are sometimes used instead of the monolithic concrete, these blocks being hollow. Partition walls are also made of these hollow blocks with as much reinforcement as circumstances require.

Duesing uses flat bars twisted while hot so that the convolutions prevent the pulling out of the bars from the concrete.

The Expanded Metal system has for its principal characteristic a net work formed in a special way by cutting slits in a sheet of steel and then pulling it out sidewise so as to produce a net work with vertical flat ribs and diamond shaped openings with the metal at the intersections solid because uncut. This metal can be used for any purpose for which wire cloth and systems of intersecting rods are used, apparently with some advantages of either strength, stiffness or cheapness over most of them. Rods, bars, straps, etc., are used as they seem to be needed as adjuncts.

The Fairbairn system for spanning wall openings has straight rods for the extrados and rods curved to fit the arched intrados, all having turns at ends to give hold on the concrete in the wall.

The Ferroinclave system uses a sheet steel corrugated in dovetail shape and used like wire cloth.

The Gesche system for walls is like the Huguet and permits making in advance and setting in place.

The Gruening system is similar to the Fairbairn.

The Habrich system uses twisted flat bars in various combinations with floor beams in making beams, floor slabs and floor arches.

The system Harel de la Noe uses steel rolled shapes and is self-supporting.

The Helm system uses independent flat bars embedded in the concrete.

The Hennebique system was brought out in 1892, the inventor having constructed reinforced concrete floors as early as 1879. For floors rods are used, one set straight and another set bent up near the points of support to pass over them, placed alternately. Sometimes the rods are used in both directions across a slab. Near the points of support stirrups may be set passing under the rods and up into the concrete, being turned over at upper ends to give a hold on the concrete. Beams have similar construction modified to suit the work. Foundations, columns, stairways, arches, dock walls, piles, sheet piles, etc., are constructed on similar principles, the straight and bent rods taking the tension and the stirrups giving resistance to shear. For arches the stirrups take the form of rods hooked about rods bearing on the main rods near top and bottom of arch rib.

The Holzer (German) system uses I-beams.

The Huguet system for walls uses vertical round bars interlaced with network. The pieces are made in factory and set in place.

The Hyatt system uses flat bars with holes punched in them through which are passed transverse wires. Floor slabs are the principal place of application, but beams have also been constructed with this form of reinforcement on the tension side.

The International system of floor construction uses wire netting supplemented by steel-wire ropes in reinforcing floor slabs and girders. The cables in floor slabs are anchored to the walls at both ends and are carried over the girders, sagging in middle of spans to lower side of floor slab, and the wire netting is on top of the cables.

The Johnson bar for use in reinforcing is a corrugated bar, rectangular in cross section and with rectangular projections on all four sides, alternating in position on adjacent sides.

The Kahn system uses diamond or other shaped cross sections of reinforcing bars which permit of shearing projecting wings for given lengths along the bar, these sheared portions being then bent to an angle of about 45 degrees with the bar, thus causing the shear members to be rigidly connected with the

tension members of the reinforcement. The shear bars may be flat bars with one end riveted to the plate and the bar then bent through 135 degrees to the position for use.

The Kindle system was one of the early American systems. The transverse beams of a floor system were formed of hollow tiles reinforced with flat iron straps suspended from the top flanges of the floor beams with transverse rods joining them to the tiles.

The Klett (German) system for floors has flat iron bars, some extending from floor beam to floor beam and bent round the upper flanges, or projecting into the next span, the bars being depressed in the center of the span to the tension side. Transverse flat or angle iron bars are used as needed, attached to the main bars at intersections.

The Koenen (German) system uses round bars hooked over the upper flanges of floor beams or anchored in walls, and depressed to bottom surface at middle of span. Concrete is filled in about floor beams, thus showing flat arch form in ceiling of room below. This system is used in this country for spans up to about 20 feet.

Kuhne's sheet metal is slit in the same manner as expanded metal, but alternate points of uncut metal are pressed up so as to form a reticulation on two parallel planes with diagonal bar connections between them. It can be used like other wire cloth and has the special characteristic of the double reinforcing giving it properly the name of trussed metal lath.

Lefort's system is like that of Boussiron and he is said to have devised it. The reinforcing rods are not connected by metal. It uses parallel pairs of rods in two horizontal planes, symmetrical about an axis.

The system of Lilienthal is very simple, with continuous wires or bars in floor slabs extending over and supported by the floor beams, whose vertical reinforcing bars are attached to the floor-reinforcing wires.

The Locher (German) system for beams uses layers of flat bars horizontal at center and near lower surface of beam and bent up toward the top surface at different distances from the center in curved form, thus carrying tension and shear in a beam supported at both ends.

The Lock-Woven Steel Fabric is a steel wire mesh locked at the intersections in the process of manufacture and used like other wire mesh reinforcement.

The Luipold system is very similar to the Hennebique.

The Luten system of arch construction uses round rods in the arch ring, following the lines of tensile stress as nearly as convenient. Its principal feature is the tie bars under the bed of the stream to which the stresses in the arch are transmitted, thus reducing materially the weight of abutments. These rods are embedded in a concrete paving for the bottom of the stream under the arch.

The Luther system is like the Huguet and is made in advance and set in place.

The Maciachini (Italian) system utilizes the principle of hooping, using four rods bent backward and forward for the four sides of a beam, the bottom and side rods being threaded together before they are put in place after the concrete has been placed for the bottom section of the beam. After placing the concrete with whatever other reinforcement is necessary, the upper rod is bent and threaded into place and the final layer of concrete is deposited.

The Matrai (Hungarian) system uses steel wires or cables sufficient to carry the entire load under tension, the concrete being used simply as filling and to distribute the weight. For floors diagonal wires are run between the main and the secondary beams as well as wires parallel to each set of beams, thus forming a close network of suspension wires about which the concrete is deposited. The wires in columns form parabolic curves, are wound about a ring at the top and hooked into anchor rods at the bottom. Walls have combinations of I-bars and rods.

The McCarthy bridge floor uses two sets of wires, one running horizontally from floor beam to floor beam and the other in suspension form passing continuously over the floor beams from end to center of the bridge, where an expansion joint for the floor is located. Each group of wires of the two sets is encased separately in concrete and these ribs below are joined by the concrete floor foundation above. Thus the wires carry the tension and useless concrete is omitted below, and the con-

crete in the upper surface carries the compression stresses.

The Melan (Austrian) system for arched floors and bridges uses I-beams or other rolled shapes, bent to the arch form and filled around with concrete. A tie rod is used if necessary. In long spans the beams become built-up girders.

The Metropolitan fireproofiing system uses I-beams with transverse two-wire cables stretched over them, on which are laid round rods at the center of the span to secure uniform position. The concrete is laid about this reinforcement. Ends of cables are hooked over flanges of beams or anchored in wall.

The Moeller (German) system for floors and beams uses flat bars in tension side of beams to which are attached short pieces of angle iron to resist pulling out. Floors are reinforced with I-beams in the concrete.

The Moreland system is like the Fairbairn, but uses bent rods in the reinforcement of the arch.

The Monier (French) system was perhaps the earliest general method of application of reinforcement to concrete. It is simply two series of wires or rods at right angles, tied together at the intersections. Floor slabs, ceilings, arches, beams, columns, partition walls, pipes, sewers, tanks, piles and all sorts of ornamental and useful objects have been made on this system and many of those in this list are merely modifications in application or in form or material for avoidance of patent, which has now expired, or for some improvement in detail. Monier cylinders have been used to surround and protect wooden piles in sea water.

The Mueller, Marx & Company's (German) system uses for floors upright flat bars extending from joist to joist, tied together with similar zigzag bars secured by iron clips. For long spans the bars may take the suspension form and are firmly attached to floor beams or anchored in walls. Stairs are self-supporting if built on this principle. A notable application of this system is to bridge abutments having only a screen wall on the face and a concrete floor behind, supported on one or more reinforced concrete walls running back into the fill of the approach.

The Multiplex steel plate floor system uses a steel plate corrugated with alternately two waves near an upper plane and

two near a lower plane, the lower corrugations resting on the floor beams, and the space above the plate being filled with cinder concrete.

The Neville system uses two sets of reinforcement in beams and connects the two sets by diagonal ties or braces, thus giving them some mutual support.

The Parmley system for sewers, conduits and arches uses bars around the arch with bent ends to engage the concrete, so placed as to resist the tension in the haunches and crown of the arch.

The Pavin de Lafarge (French) system for beams uses two rods at top and bottom tied together by zigzag flat bars tied to the rods, or round wires or rods wound once around each rod at each turn. Floors and ceilings are similar to Monier constructions, floor slabs often being made on the ground and laid in place after the rest of the construction is finished. For pipes longitudinal rods are used wound spirally with small wire or hooped at intervals if section of reinforcing bar is heavier. Reservoir covers and tanks are readily constructed on this system.

The Picq system is another analogous to the Hennebique, using rods near lower surface of slab and bent rods which are near upper surface at points of support and near lower surface in middle of span.

Piketty (French) prefers round rods, gradually increases the angle of his transverse reinforcement for beams, from vertical at the center to 30 degrees with the vertical near the points of support, inserts his reinforcing rods where they are needed to carry tension.

Rabitz (German) uses wire network with diamond or hexagonal meshes in rolls. A specialty in this system is the protection of reservoir and canal slopes with reinforced concrete slabs.

The Ransome system uses square bars twisted cold with a definite angle to the twisted surfaces. Forms of construction are similar to those in other systems.

The Rapp floor has inverted T-bars, supported on the flanges of floor beams, which carry on their flanges brick or tile upon

which a layer of concrete is deposited. For arch form of ceiling the T-bars are bent to the form desired.

Rechtem, Vernig and Dopking (Dutch) piles have I-beams framed together and embedded in concrete.

The Renton system of fire-proof floors consists of a flat cinder concrete arch reinforced with barbed wire, there being various designs to meet conditions as to strength, kind of flooring material, depth and weight of floor required, etc.

The Roebling fireproofing system uses the ordinary floor beams and built steel columns, protecting them from fire by concrete surrounded by woven wire on which concrete plaster is laid. Floors, when arched, are stiffened by steel rods woven into the wire cloth, which is arched as a support for the concrete in laying. The ceiling is of reinforced wire cloth supported from the crown of the arch, on which the plaster is laid. For flat floors, flat reinforcing bars on edge are used, clamped to the supporting beams and connected by flat bar separators. The concrete is preferably made with cinders or other fireproof material. There are several modifications of these central ideas, the intention being always to protect the steel from the action of fire.

The Roessler system uses flat bars which have no metallic connection with each other.

The Rossi system uses wires or bars bent in sinusoidal form.

The Schlueter (German) system uses intersecting bars tied together like the Monier system, except that the bars run diagonally.

The Siegwart (Swiss) system for floors uses hollow beams which are made in a factory and when cured they are taken to the building and laid in place side by side and grouted with cement. The beams are hollow and reinforced with rods and stirrups as the spans and loads may require. Deeper beams are constructed as supports for the ends of floor slabs when spans are long enough to require them.

The Staff system uses flat bars stamped with circular projections about and into which the concrete is deposited.

The Stellet system is similar to the Coignet and depends largely upon the diagonal bracing between the main reinforcing rods.

The Stolte (German) system uses hollow concrete blocks which have longitudinal hollows between which upright flat bars are embedded. The blocks are joined with cement mortar and the floor slabs thus formed are supported on steel or timber floor beams.

The Thacher system uses flat bars in pairs, one bar near extrados and one near intrados, each bar having projections for increasing their hold on the cement. The bars are bent in arch form and the system is similar in intent and application to the Melan system, but there is no connection except the concrete between the bars of a pair. Mr. Thacher also has a round bar which is flattened out alternately on planes at right angles to each other, which is of more general use than the bar first mentioned.

The Turner system uses in columns a grill of vertical rods banded at intervals by strong riveted hoops with one of the rods bent outward into each beam resting on its top, the whole wrapped or hooped with netting. The column thus acts as a whole and is thoroughly bonded to the adjacent beams. In the construction of beams he makes them continuous over their points of support, thus requiring the reinforcing metal to change position from the lower side of the beam in the center of the span to the upper side over the supports, and supplying the proper resistance to shear in the length of beam in which this change in location takes place. The centering to support forms is reduced to a minimum and on many spans is omitted altogether for beam construction.

The Vallerie and Simon (French) system as applied to reservoirs consists of rods bent to the circular form of the reservoir and attached at proper distances apart to temporary uprights until the vertical rods could be put in and tied to the circular rods, and the concrete could be placed.

The de Valliere (French) system uses a rod on which is threaded a wire bent back and forth, each loop extending a given distance from the rod and on its return forming an eye for the rod to pass through. The rod being threaded into these loops, they are spread out along the rod to any spacing desired. Floor slabs have series of these rods and wires, and floor beams may have one, two or more as size and loads require.

The Veyhe system is similar to the Fairbairn.

The Viennot system is similar to the Busso and Boussiron.

The Visintini (Swiss) system is one of lattice girder construction, being in appearance a system of girders on the same principle as a steel lattice girder. The reinforcing bars are found on all the lines of possible tension. The members of a structure are made in a factory and laid in position after the concrete has thoroughly set. The latticed floor sections are laid side by side and grouted together. When the length of spans requires, larger floor beams of similar construction are put in as supports for the floor sections. Stairways, columns, walls and partitions are readily made on this system.

The Von Emperger reinforced arch uses instead of the arch ribs of the Melan system bars of metal embedded in the concrete near extrados and intrados and parallel thereto, and connected by bars, this forming a less rigid truss system.

The Walser-Gerard (Swiss) system uses two sets of rods in beams and floors, one set near upper surface and one near the lower and a transverse wire entering from an adjoining slab, passing round in succession rods in the upper and lower sets alternately and on into the next slab. This wire may run vertically between sets or on a diagonal to aid in taking care of shear. This interlacing may be run on diagonals and verticals over the whole length of the beam, the verticals being spaced to correspond with the shear stresses.

The Wayss system is a modification of the Hennebique, changing the form of flexure of the bars near the points of support.

The Weber system for chimneys uses T-bars connected at the intersections by special forms of sheet metal clamps.

The Weyler system uses light steel strips with large circular holes stamped in them and bent to show in cross section of slab the I-form. They extend almost the full depth of the floor slab.

The Williams (English) system for piles uses an I-beam, sharpened at one end by cutting away the web and forging the flanges together to a point, flat steel tie bars fastened near ends of pile and trussed out to serve as stiffeners under heavy loads, and hoops of flat steel to strengthen the concrete against excessive compression. Piles are closely bound to reinforced con-

crete beams serving as caps. In floors are used longitudinal I-beams with flat bars bent over and under them transversely showing lenticular form in view of cross section of floor. In beams of long span the reinforcement is of angle irons near top and bottom of beam, connected by diagonal flat bars riveted to them.

Wilson's system uses flat bars suspended from the top flange of the floor beams by hooking around them, the bar in the center of the floor slab span being near the lower surface, and near the top at the points of support.

The Wuensch (Hungarian) system uses T-shaped beams, the flat floor slabs resting on the upper flanges of floor beams and the arched lower section resting on their lower flanges, the T-bars being riveted thereto. For arches angles may be used and the entire space between arch ring and horizontal extrados filled with concrete. Mr. A. W. Buel has modified this by making both extrados and intrados curved and adding longitudinal angles connecting the ribs, with diagonal bars connecting the upper and lower ribs.

REINFORCED CONCRETE DAMS.

The Ambursen and Sayles method of building reinforced concrete dams uses an inclined concrete slab continuous from pier to pier, reinforced with Thacher bars and expanded metal, supported on solid concrete buttresses about 12 inches thick and 6 feet apart. It is a gravity dam, although a large amount of concrete is saved in the spaces between the buttresses underneath the concrete slab. Several of these dams have been constructed in the last two years.

CONCRETE GRAND STANDS.

Washington University built a grand stand for its athletic field which was in use by the St. Louis Exposition in 1904, of concrete with steel reinforcement in the seats and in the front and rear walls, at a cost of $32,000.

The Harvard Stadium is another notable example of this application of reinforced concrete.

Perhaps the earliest structure of this sort is the grand stand at the baseball park in Cincinnati, O., built according to the Ransome system.

CROSS TIES FOR RAILROADS.

There are now innumerable designs and patents for the application of concrete, plain or combined with wood or steel, to the manufacture of cross ties for railroad use. The longitudinal beam for supporting the rail has been used to some extent for street railways, but is not sufficiently flexible for steam or interurban railroad conditions. The Kimball tie has two rectangular blocks of concrete, one for each rail, connected by two channel bars. Hard wood blocks on top of the concrete carry the rails. The Burbank tie is a solid concrete tie with a special form of twisted steel plate embedded in it. These represent the principal classes of reinforced concrete ties.

CONCRETE PILES.

The Raymond concrete pile has a round steel bar in the axis of the pile and three smaller bars equally spaced around the circumference. The apparatus for forming these piles in place is somewhat elaborate, but the piles are very rapidly constructed.

The Simplex concrete pile is reinforced with expanded metal in cylindrical form. It is constructed in place, the previously formed concrete head being driven to place by means of a steel cylinder fitting it, into which the expanded metal cylinder is slipped and the concrete is poured, the driving cylinder being withdrawn as the concrete is filled in. For piles in water an outer steel cylinder is slipped into place to form the outside of the pile.

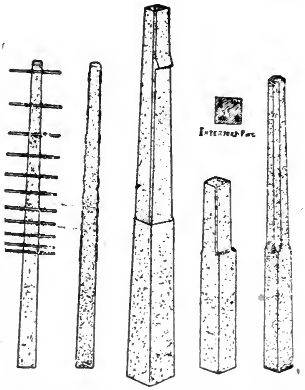
Many of the preceding systems of reinforcement can be applied to the construction of piles, as is stated in connection with the mention of several of them.

FENCE POSTS.

The number of patents on reinforced fence posts is only exceeded by the number on hollow concrete blocks. Wooden rods were first used and they were soon displaced by iron or steel, including gas pipe, round, square, corrugated, or twisted rods or wires, barbed wire and cables. The methods of fastening the fence to the post are various also, including wooden plugs or blocks as nailing pieces, various forms of clamps, eyes, wrapping wires and staples. Some use simply holes in the

post through which bolts, staples or wires can be passed. All these chances for variation give rise to many patents.

Posts are usually made of gravel, not too large in size. Many of the natural mixtures of gravel and sand are nearly correct and can be tested by trying the effect upon the percentage of voids of adding sand to or subtracting it from the natural mixture. The proportional amount of sand depends upon the



REINFORCED CONCRETE FENCE POSTS. SHOWING LINE, CORNER, STRAINING AND ANCHOR POSTS AND SECTIONS.

variety in sizes of the gravel and that mixture should be used which, when made into concrete and rammed in place will give the smallest volume of concrete. An average proportion of cement for good work is about 1 to 4 of the mixture of gravel and sand. If there is too little sand the proportion of cement must be increased. It may be necessary to increase it also if there is too large a proportion of sand. The voids in the aggregate must be filled by the cement and, except a small excess to insure this, a larger proportion of cement is unnecessary. An easy approximate way to find how much cement is needed is to fill a box of known size with the gravel and then see what volume of water can be added to the box without overflowing, this will be the volume of cement to be used, adding about 10 per cent. if it is measured loose or if the mixing is not most thoroughly done.

Molds for posts are usually made of wood, metal ends being desirable. It is well to mold posts on a bed on which they can remain until they are cured, and if they are moved away from

the machine or place of molding for storage the pallets must be stiff and unyielding and must be handled without shocks. Many posts are weakened if not destroyed by breaks or shakes in handling before the cement has fully set. Sometimes molds are made in sections so that two to five posts can be made with the same setting. The reinforcing wires must be carefully placed so that the concrete can be thoroughly rammed, and the placing of the fastening devices must be provided for in the faces of the molds.

Posts should be thoroughly cured, being sprinkled at intervals for some days. Posts are frequently used in three or four weeks after making, but should be left to cure for three to six months or more for the best results.

REINFORCED CONCRETE RESERVOIR COVERING.

The roof of the covered reservoir at Newton, Mass., is supported on brick piers 20 inches square, each panel being 11 feet $10\frac{7}{8}$ inches by 11 feet 8 inches.

The covering of the reservoir may be briefly described as a monolithic floor of concrete, reinforced with ribbed steel bars, and supported on the tops of 12-inch I-beams, the latter also incased in concrete. The I-beams weigh $31\frac{1}{2}$ pounds per foot and were cut long enough to span two of the 11-foot 8-inch spaces and leave $\frac{1}{4}$ inch for expansion. The specified loading is 275 pounds per square foot, plus the weight of the flooring. There was 150 pounds per square foot of loam placed on the reservoir, and it was estimated that 125 pounds per square foot would be equivalent to the maximum strain which might come on the concrete due to any moving load such as a crowd of people or teams passing over the reservoir. Such a load, however, would be extremely unlikely to occupy a large portion of the reservoir at any one time, so that it need only be used in determining the strength of the concrete-steel filling between the beams.

The flooring itself has a span of 11.9 feet, center to center of the I-beam supports. It consists of 7 inches of Portland cement concrete in which are embedded $3\frac{1}{2}$-inch Columbian bars spaced 22 inches apart and resting directly on the I-beams. This is but a sample of many similar structures.

REINFORCED CONCRETE GIRDERS.

At Purfleet, England, is a reinforced concrete girder, having a straight lower chord of 60 feet length, a curved upper chord, giving a depth of girder of 6 feet at the center, and verticals dividing the web into panels 5 feet long with clear open spaces in each panel. The floor is also of reinforced concrete. The following is a brief description of the girder:

The upper chord is 18 inches wide by 9 inches deep, and is reinforced by eight 1⅞-inch round bars. Cross bars are inserted transversely at frequent intervals, and serve to check any tendency of the concrete to bulge laterally when the load comes on the bridge. The lower or tension chord is also stiffened by eight 1⅞-inch round bars, which are connected together by stirrups of No. 12 S. W. G. iron 2 inches wide. These stirrups are placed at intervals of every 10 inches and add much to the solidity of the compound chord. The verticals are cross-shaped in plan, each arm of the cross being 7 inches long by 5 inches thick. Vertical bars, having hooked ends which lap over the main bars in the upper and lower chords, are used to strengthen these verticals. To avoid delicate adjustments these vertical stiffening bars are made in two parts, which, after putting in place, are securely bound together by iron wire. Along the top and bottom edges of each panel opening strength is afforded by two ¾-inch bars extending from end to end of the girder. Iron reinforcing bars are carried round each corner of the panel opening and prevent any tendency of the concrete to crack or open at these corners under the shearing stresses.

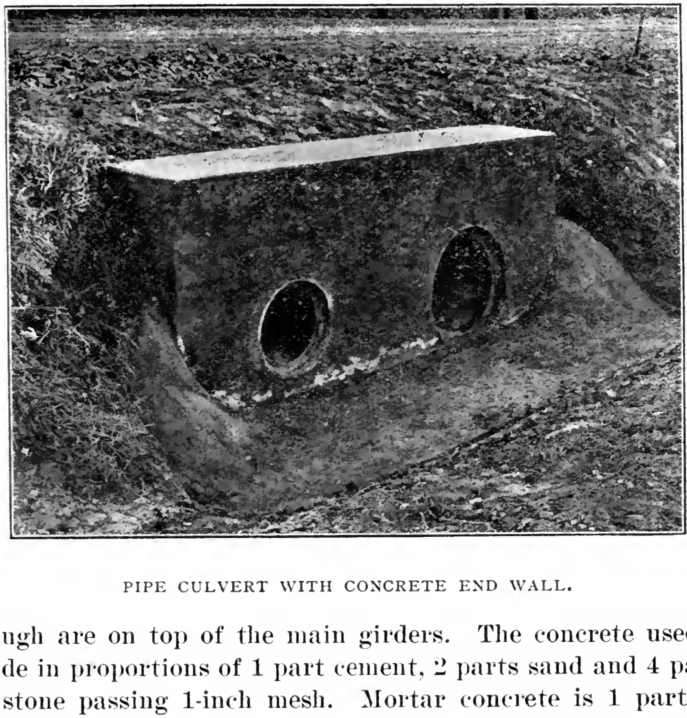
The bridge on the Wabash railroad over the main drive in Forest Park, St. Louis, Mo., is a through plate girder, on account of the requirements of head room. The abutments are hollow and are built of reinforced concrete. Curved ornamental wing walls are also of reinforced concrete. To conceal the steel girders, ornamental concrete balustrades have been constructed. They are supported on brackets from the main plate girders and are fully reinforced with steel bars of the Johnson type.

A similar structure more elaborate and more extensive is provided for the River Avenue bridge in Indianapolis, under construction. In this case the plate girders are located between the roadway and the sidewalks. The ornamental gir-

ders form the outside girders supporting the sidewalks, but are aided in their work by brackets from the main girders. The specifications for these girders and for the reinforced concrete bridge floors will be found in the following chapter.

BRIDGE FLOORS.

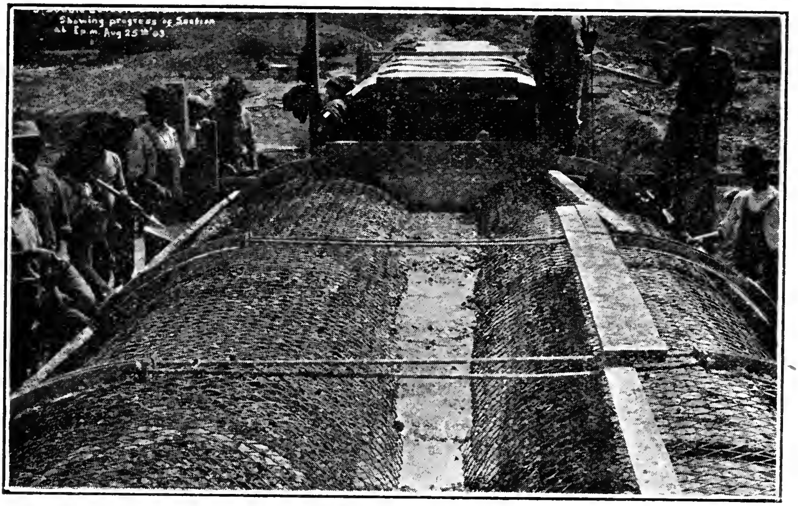
The Wabash railway has adopted standard designs for reinforced concrete bridge floors. One design for through bridges uses a reinforced concrete slab, 6 inches thick, supported on 15-inch I-beams 18 inches apart. The concrete is carried up the sides of the main girders to form a trough in which to deposit the ballast for the roadbed and keep it away from contact with the steel. This floor may be located anywhere from the bottom of the girder up. For deck bridges the concrete slab and



PIPE CULVERT WITH CONCRETE END WALL.

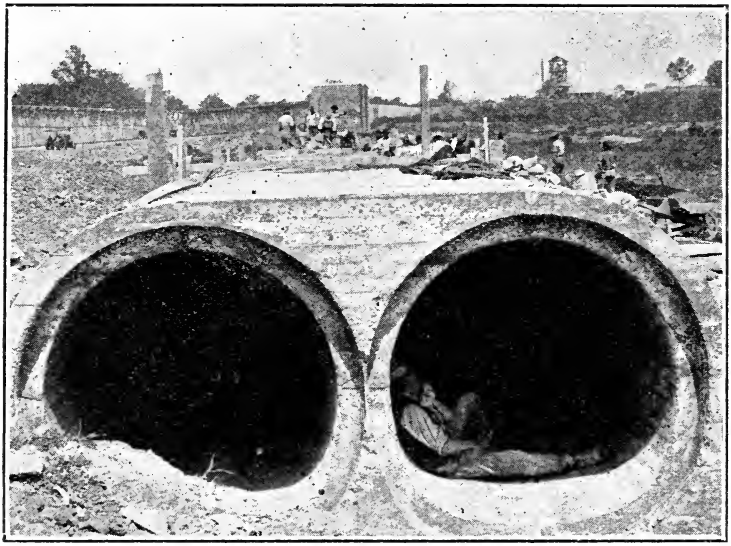
trough are on top of the main girders. The concrete used is made in proportions of 1 part cement, 2 parts sand and 4 parts of stone passing 1-inch mesh. Mortar concrete is 1 part cement and 3 parts coarse sand. Reinforcing bars are ½-inch.

The River Avenue bridge in Indianapolis, is designed with



DOUBLE CONDUCT OF NEWARK, N. J., WATER WORKS. SHOWING METHOD OF REINFORCEMENT.

a reinforced concrete floor under roadway, steel railway tracks and sidewalks, using corrugated bars and supplying troughs

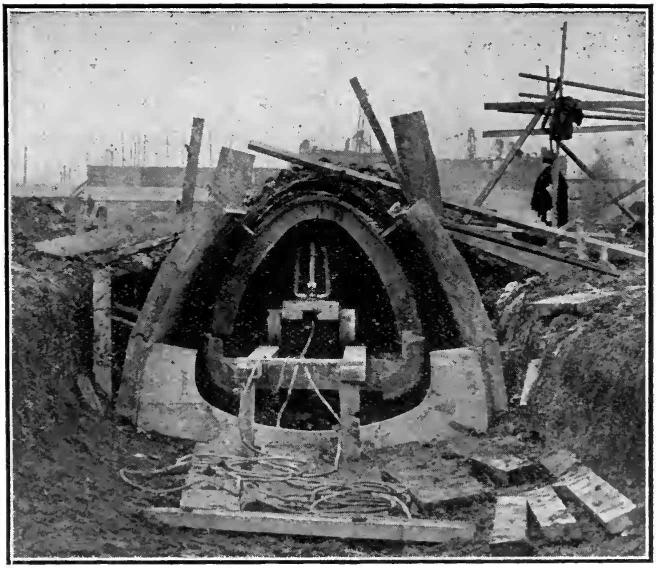


SHOWING COMPLETED SECTION.

for the ballast of the street railway tracks, the roadway paving being laid on the concrete directly.

CULVERTS FOR HIGHWAYS.

The Iowa State Highway Commission recommends in place of pipe or wooden box culverts in highways rectangular reinforced concrete culverts. The reinforcement is woven or barbed wire, or for longer spans is of steel bars, placed near the



CONDUIT OF INDIANAPOLIS, IND., WATER WORKS. REINFORCED WITH EXPANDED METAL.

inner or tension side. The concrete bottom is first formed, then the sides and top in plank forms and wing walls are constructed, especially on the up stream side. Care must be taken to put the reinforcement in its proper place and to stretch it so that it will do its full duty in aiding the concrete to carry any tension which may come upon it.

REINFORCED CONCRETE CONDUITS AND SEWERS.

A reinforced concrete conduit has been constructed for an irrigation system near San Antonio, Tex., which is under pressure as an inverted syphon, and exemplifies the application of

this method of construction to conduits and sewers, whatever system of reinforcement may be used.

REINFORCED CONCRETE BUILDINGS.

This is not the place for detailed descriptions of reinforced concrete buildings. A few of the most notable examples may be mentioned as indications of what has been done recently in

A REINFORCED CONCRETE BUILDING IN HALIFAX, N. J.

this line. The Ingalls building in Cincinnati, O., was the first large building built on this system. The U. S. Naval Academy at Annapolis, Md., has recently built a chapel of reinforced concrete, one feature of which is a dome 69 feet in diameter, with a cupola 110 feet above the main floor and a second cupola 33 feet above, supporting a lantern 48 feet high. The

plans for a reinforced concrete round house on the Canadian Pacific railway look very much like those for a frame structure. The walls are plain concrete. The columns supporting the roof are I-beams surrounded with expanded metal in concrete; roof braces being angle iron, encased in concrete. The radial roof beams are I-beams enclosed in concrete. The transverse roof beams are of concrete reinforced with rods and expanded metal, and they support reinforced concrete roof slabs of similar construction, using cinders to save weight.

ADHESION OF CONCRETE AND STEEL.

Professor Monsch, of Zurich, Switzerland, found the following results of tests of the adhesion of cement and sand mortar to steel rods, pulled out endwise:

Proportions Cement	to Sand.	Percentage of Water	Adhesion Lbs. per Sq. in.
1	1	10	654
1	2	15	697
1	3	——	569
1	4	——	540

Steel plates torn off by pull normal to the surface, plates being $1\frac{3}{8}$ by $2\frac{3}{4}$ inches, and mortar in which they were set being 31.2 pounds of cement to 1 cubic foot of sand, showed the following results:

Time of Setting.	Adhesion.
2 days	4 lbs. per sq. inch.
7 "	9.5 " " " "
12 "	13.5 " " " "
17 "	16.2 " " " "
24 "	18.5 " " " "
27 "	18.8 " " " "

Prof. Charles M. Spofford gives as the resistance of round and square rods to pulling out of concrete of 1 part cement, 3 parts sand and 6 parts stone after one month, 219 to 274 pounds. Flat bars had resistance of 42 to 226 pounds, and three special forms had resistance of 138 to 508 pounds. Minimum embedding of plain bars and rods was 24 inches and of special forms 12 inches, and in nearly every case the minimum resistance was by rods with maximum length embedded in the concrete.

PRESERVATION OF STEEL IN CONCRETE.

A sidewalk around Bowling Green Park, in which were embedded steel rods when the walk was laid in 1883, was recently torn out in constructing the subway in lower Broadway, New

York City, and the rods were found to be in perfect condition.

The effect of concrete on iron was shown by embedding a piece of galvanized iron in cement for six months. It was then found that the galvanizing had all disappeared but the iron was clean and bright.

Steel has rusted in concrete but the reason has usually been found in too dry mixtures, especially of cinder concrete. The true protection seems to be given by a thin film of cement on the surface of the steel and this can not be insured unless the mixture is wet enough to carry the cement to the steel and deposit it there. The cement apparently removes any rust which it finds and prevents the formation of more. Some cements have been successfully used as paints for the protection of steel.

In 1892 Wayss and Freytag, of Germany, built a water pipe system of concrete reinforced with small wires. Recent investigation of one pipe relaid in a new location showed the reinforcement to be still in perfect condition.

CONCRETE AS FIREPROOFING MATERIAL.

W. N. Hazen in a report on the Baltimore fire, says:

For the fire protection of steel the first requisite is conscientious workmanship. Lime or its products have proved worthless. All stones in bulk spall and are not to be trusted. Broken stone in concrete does not act the same as in a solid mass, as evidenced by the floors of the United States Fidelity & Guaranty Co.'s building. Concrete stood the test remarkably well. Terra cotta should be heavier, and under no consideration should it be used in single thickness of ⅝-inch. For vaults I would recommend that a rich mixture of cement and sand be used for inside and outside, with at least 5-inch terra cotta blocks forming the core. That good, soft-burned brick will stand fire is without question. Where facing brick is used, it should be substantially bonded to the main wall, preferably with brick.

John R. Freeman, in his report to the National Fire Underwriters on the Baltimore fire, says the following:

The behavior of Portland cement compounds was in marked contrast to the plaster of paris compounds. After studying the Baltimore ruins I am very optimistic on the fire-resisting quality of Portland cement construction. One great advantage of Portland cement construction is that if you put it in wet and soft, and almost semi-fluid, it will fill the voids and

leave no bad blow holes or cavities, even under mediocre care and incompetent supervision. The careless workman thus has less chance to get a poor joint than in brick work. With the modern finely ground cements, if a slight excess of cement is used above that theoretically needed to fill the voids between the grains of sand, and, if the whole is thoroughly mixed, as it can be easily by modern machines for this purpose, it excludes air and moisture and opportunity for corrosion. The Portland cement concrete possesses far greater tensile strength and shearing strength than the best brick work, and, in brief, I believe that it presents a material for fire-resisting construction which is not excelled by anything yet known.

The Engineers' report to the Board of Fire Underwriters on the Horne building fire in Pittsburg, contains the following paragraphs:

Owing to the fact that steel columns or girders or beams after being subjected to a long-continued fire will assume the same temperature as fire-proofing, and owing to the fact, furthermore, that the rate of expansion of the steel is much greater than that of the fire-clay tile, destructive movements are permitted which, as shown in this experience, will result in considerable damage, and which damage will increase in direct proportion to the height of the building.

In view of these important developments, it is our opinion that important structures of this class should have a radically different method of fire-proofing. The fire-proofing should be in itself strong and able to resist severe shocks, and should, if possible, be able to prevent the expansion of the steel work.

There seems to be but one material which is known that could be utilized to accomplish these results, and that is first-class concrete. The fire-resisting qualities of properly made concrete have been amply proven to be equal to, if not better than, fire-clay tile, as shown by the series of tests carried on by the building department of the city of New York.

From the experience gained in street railway construction in laying continuous rails, it is to a large degree possible to prevent the metal from expanding. In street railway work this has been accomplished merely by the adhesion of the pavement to the side of the rails. In building construction the same results could be obtained by encasing the columns and girders with concrete placed directly against the steel work. The adhesion of the concrete would to a large degree prevent unequal expansion of the concrete and steel. The floor arches should also be constructed of concrete, but of sufficient depth to be able to resist lateral forces. With the prevention of injurious expansion and the protection of columns with mater-

ials that can stand severe shocks of any nature whatever, the modern steel frame constructed building would be more thoroughly protected against fire.

Both Siegwart and Visintini reinforced concrete beams are fireproof. The Siegwart beams, which were tested in New York city in August, 1904, withstood a fire of 1,800 degrees F. all right.

The Visintini beams stood fire tests at the London Exposition fire in 1903, and a new test, which was made in the autumn of 1904, in Trieste, showed the best results for the protection of the iron against the fire, although the concrete protecting the steel bars is only 3/8-inch thick. The test was carried out on two girders, each 10 inches high, 8 inches wide, and a length of about 17 feet; between the two beams was supported one Monier slab, 1½ inches thick and about 4 feet wide. These two supports, attached to the beams, were 1½ inches high and 1¼ inches wide. The clear span of the girders was about 16 feet. The floor had a dead load of 32 pounds per square foot, and was loaded with 2,000 pounds. The fire, which was made to test this floor, lasted half an hour, and was of a temperature of about 2,000 degrees F. It was extinguished by water, then the floor was allowed to cool off and was loaded with 2,620 pounds, which is nearly five times the safe load. The girder showed not the slightest cracks—only a deflection of about ¾ inch, and broke down under a load of 2,800 pounds. The beams had an age of only a few days.

A floor made of steel beams, 5-inch ribbed bars of the Columbian system, spaced 2 feet apart and embedded in 8¼ inches of concrete, was recently subjected to severe tests to show the value of concrete as a fireproofing. The main body of the concrete was made in proportions of 1 part Portland cement, 2½ parts sand and 5 parts broken stone, and its under side was veneered with 2 inches of cinder concrete. After a test loading of 1,000 pounds a square foot, the floor was subjected to a temperature of about 1,700 degrees by fire for 2¼ hours. Water was applied from a fire stream, the fire repeated for 38 minutes and water again applied. The floor was again loaded with 1,650 pounds a square foot. The result was a deflection of 1⅝ inches, 15-16 inch of which was

due to the fire, a few cracks in the ceiling, and the washing away of some of the cinder concrete by the fire stream, in one case to a depth of ¾ inch. The test of the fireproofing and floor was highly satisfactory.

Tests of concrete blocks at Oklahoma City, Okla., and their successful resistance to fires in Estherville, Iowa, and Carbon, Ind., are additional evidence of the fire-resisting qualities of concrete.

The tests in progress at the fire testing station of Columbia University, one or two of which have been published, are finding additional valuable evidence on this subject. The first of these tests the results of which were published, was made in a test building, the roof of which was built as a concrete floor reinforced with Kahn bars. The stone used was trap rock. The floor stood a temperature averaging 1,200 degrees F. for four hours, with very little injury except pitting of the surface of the concrete ceiling where the stream of water used in extinguishing the fire struck it, a few small cracks and a slight increase in deflection under the load of 150 pounds per square foot which the floor carried. The test was eminently successful and the method of construction and the materials were approved in New York city.

FACING OF CONCRETE WORK.

Concrete which is deposited in molds takes any imperfections of surface which the molds may have. It is necessary, therefore, to have the molds as perfect in form and finish as the concrete is expected to be. Even the grain of the wood of a form is shown in a fine grained cement surface. If the timber is used for forms for smooth concrete work it must be planed perfectly smooth and must be clear and as straight grained as possible. The planks must be joined in such manner that the expansion of the timber when moisture is absorbed from the concrete will not break the continuity of the surface, and they must be laid together so that adjacent planks will form an unbroken surface. One edge of a plank may be beveled almost to a sharp edge and then laid on the preceding plank with this edge adjacent to it. When the planks expand this thin edge will be crushed and the triangular space behind it partly filled with the crushed wood, thus reducing the danger

of deformation of the concrete surface. The surface of the planks may be filled with soap or paraffine to prevent the appearance of the marks of the grain on the concrete and the joints may be filled with putty, soap or plaster of paris. Crude petroleum may be used to fill the pores of the wood. Occasionally strips of cloth are used to prevent the cement mortar finding its way into the joints between boards. For very fine work the molds may be covered with plaster of paris. A sand finish is also possible by using oil or varnish on the molds and sanding the surface before the oil is dry. The mold may be lined with sheet iron or steel to give a perfectly smooth surface.

The finer the grain of the surface, the greater care must be to prevent form marks. With a coarse concrete the joints between boards may be the only troublesome thing, but if a finer concrete or mortar is used on the surface much more care must be taken to prevent marks.

Joints such as are seen in ashlar masonry can be indicated by tacking to the forms triangular strips of wood, sheet iron or sheet steel, which will project into the the concrete and form the triangular depressions which represent the bevels cut on the edges of such ashlar masonry. Any other form of joint can be made in like manner. These joints can be used to cover the junctions of metal sheets when molds are lined with sheet iron or steel. Ornamental moldings and panels can be constructed in place by making the molds of proper form and using fine stone in making the mortar and concrete. Many ornamental portions of a structure can be made more satisfactorily in separate molds and set in place as stone would be set. The section on artificial stone gives descriptions of methods of construction.

To give a mortar face to a wall, a special mixture may be deposited next the form as the concrete is deposited, which must be an inch or more in thickness so that stones from the concrete will not work through. Frequently this mortar face is produced by spading back the concrete from the form, thus forcing the stones back from the face and allowing the mortar to come to the front. Special tools may be used for this work. In other cases a plank is set next the form and is removed after

the concrete is in place, its space being filled with the face mortar. A better method is to use a plate partition set the thickness of the mortar face from the mold. The face mortar is deposited and the plate is withdrawn as the concrete backing is deposited, thus insuring complete bond of the face and backing.

There are several methods of treating the surfaces of concrete structures after the molds have been removed in order to improve the appearance of the face.

The New York Central railroad specifications frequently require the following procedure when a mortar face is used. Hard soap is used to fill joints in the forms and the matched pine surfaces are painted with soft soap. While the concrete is still green after the removal of the forms the surface is rubbed with fine grained white fire brick, or with cement brick, made 1 to 1, into which handles have been cast. The surface is then dampened and a brush coat of a 1 to 1 grout with fine sand is applied. This is rubbed in with a wooden float. A circular motion is given to brick or float and the entire surface is made as uniform in texture and color as possible. Sidewalk edgers and jointers are used in making corners, re-entrant angles and joints.

With green concrete a very good effect can be secured in this way, using water to wash off the surface as the state of the concrete will permit.

Railroads use for less conspicuous work a wash made of 1 part cement and 2 parts sand applied with a brush and of a consistency of whitewash, applied after any cavities in the face of the concrete have been neatly filled with mortar of the same proportions as the original, and any marks of joints in the forms have been rubbed off. The mortar filling should be well rubbed in. Several specifications for finishing faces of walls will be found in the next chapter.

The Wabash railway uses for facing concrete abutments a wash of one part plaster of paris and three parts of cement made very thin and put on with whitewash brushes. It is reported to be very satisfactory.

A coat of cement plaster an eighth of an inch thick or more is sometimes applied as a finish. Occasionally such a coat

keeps its place and makes a fairly good appearance, especially if it is applied when the concrete is quite green, the forms having been taken off at the earliest possible moment, but the most frequent experience is the cracking of the plaster and ultimate scaling off in sections.

When special kinds of stone are used, such as crushed granite, quarry waste of Bedford stone, or even uniform fine gravel, a handsome finish can be obtained by dressing the surface of the concrete as stone would be dressed, with point, pick, chisel or similar tool. Hammers would not be satisfactory unless the concrete had become very hard. Any stone can be imitated by using the same stone crushed in the concrete and coloring the cement and then dressing the face as may be desired. A pneumatic hammer with a number of points may be used. The stones in the surface concrete must not be more than ¾-inch and the concrete must not be too green. On the other hand, if it has set too long the work will take greater time and expense.

Concrete slabs or artificial stone may be used as facing for monolithic concrete; also natural stone and brick. Natural stone has been much used for some years, especially in facing arches and piers, but as men become more expert in finishing concrete surfaces, concrete or artificial stone is taking its place and as the troubles with expansion and surface cracks are removed, the necessity for facing is removed so that there is an increasing tendency toward the use of concrete without facing.

The facing of a bridge in the National Park at Washington, D. C., was made according to the following specification:

The concrete, which will be on the exterior faces of the bridge and the parapet walls for a thickness of 18 inches, will be made of gravel and rounded stone varying in the concrete below the belting course between 1½ and 2 inches in their smallest diameters. This gravel will be mixed in the concrete as aggregate instead of broken stone. The mixture will consist of one part Portland cement, two parts sand and five parts of aggregate. The parapet walls will be made in a similar manner, with the aggregate composed of gravel not exceeding 1 inch in its smallest diameter. When the forms are removed the cement and sand must be brushed from around the face of the gravel with steel brushes, leaving approximately half of the gravel exposed.

The line of the roadway, as indicated in the drawings, will be marked by a belting course of rock-faced, roughly-squared stones, or large cobble stones from 6 to 8 inches in size, and a row of rounded cobbles will be inserted below the top of the parapet walls, both on the outside and the inside, as shown on the drawings, composed of stone between 3 and 4 inches in their smallest diameters.

The soffit of the arch shall have a mortar face of at least ½-inch thickness, composed of one part cement and two parts sand. This facing must be built up at the same time as the concrete.

Preliminary experiments showed that the concrete was too green when 12 hours old and too hard when 36 hours old to be brushed properly, but that good results could be obtained when the concrete was about 24 hours old.

CRACKING OF CONCRETE.

The cracks which occur in concrete may be assigned to two general classes, those which are merely surface cracks and those which extend through the mass.

The fine hair cracks which appear on the surface of some cement work are attributed to several causes and some of them have not been very satisfactorily explained. If the surface is too thoroughly troweled in finishing, or if the concrete forms a more or less continuous skin on the surface, the difference in constitution of this thin neat cement skin and the concrete below is sufficient to cause difference in contraction in setting which produces fine cracks in the surface, which do not enter the concrete. This cracked skin is soon worn off a sidewalk or floor, but a vertical wall or the risers of a stairway retain the cracks often with considerable detriment to their appearance. The rubbing which is described in preceding paragraphs as specified by the New York Central railroad is one way of removing the objectionable layer from the surface. Cement washes which are not well rubbed in and cement plasters are subject to the same troubles.

Cracks in the body of concrete are usually due to the expansion and contraction of the mass, with changes in temperature. Some of this effect has been attributed to contraction of the concrete in setting.

Professor W. D. Pence of Purdue University made some ex-

periments to determine the coeefficient of expansion of concrete which he reported to the Western Society of Engineers. The concrete was made according to Thacher's specification, given in the following chapter. The temperature was changed by means of a steam jacket surrounding the bar of concrete and the expansion and temperature were observed by means of suitable instruments. The results of four tests of bars made of 1 part Lehigh cement, 2 parts sand and 4 parts broken Bedford stone ran from 0.0000052 to 0.0000057 and averaged 0.0000054 per degree of temperature change. Three results with Medusa cement and Kankakee stone averaged 0.0000056. The coefficient of expansion of a bar of solid Kankakee stone was found to be 0.0000056. One experiment on concrete, 1 part Lehigh cement, 2 of sand and 4 of gravel gave a coefficient of 0.0000054. Three experiments on concrete, 1 part Medusa cement and 5 parts gravel gave an average coefficient of 0.0000053. The average of all results for broken stone concrete was 0.0000055 and for gravel concrete was 0.0000054.

Professor Hallock of Columbia University gives 0.00000561 as the coefficient for mortar 1:2 and 0.00000655 for broken stone concrete 1:3:5. The latter figure is approximately that for the linear expansion of steel.

The only method of preventing injury to the structure in strength, stability, or most often in appearance only, is to design it in such manner that the change in volume is properly taken care of. The method ordinarily applicable is to make joints entirely through the concrete, that the effects of change of volume may be concentrated at these joints and thus preserve the integrity of the mass of concrete. Special designs of of joints must be made if they must be waterproof or if the sections must be bonded together to act as one. The cracking of the concrete occurs in a monolithic structure at intervals averaging about 30 feet and it is customary to make joints at distances apart of 25 to 50 feet. If a stone or brick facing is used there must be similar provision of joints in both backing and facing. Stone masonry and brick masonry to a less extent are subject to similar cracks but, being usually less homogeneous, the cracks occur oftener and along the faces of stones or bricks rather than directly through the mass.

METHODS OF CHANGING TIME OF SETTING OF CEMENT.

Various chemical mixtures are in use for hastening the setting of cement. One of these consists of four different substances, the action of which seems to be to produce an amorphous silica which is in very small proportion to the amount of material in the mortar in which it is used. The mixture certainly hardens the concrete rapidly and thoroughly. It has been suggested by a chemist that the result is obtained by the action of the small amount of amorphous silica put into the mortar in starting a form of crystallization favorable to rapid hardening. The mixture contains as by-products of the chemical actions taking place before it is completed ready for addition to the mortar, some sulphate of iron, which may discolor the surface, some sulphate of soda, which may produce efflorescence and some lead salts, which, so far as they are located on the surface, may darken in a smoky atmosphere.

Chloride of calcium is frequently used for hardening cement quickly, small quantities having this effect, while larger quantities may delay the setting.

Chloride of barium is reported by A. Moffatt, chemist, to be the most satisfactory of this class of substances for hastening the hardening of concrete.

Sulphate of lime or gypsum retards temporarily the setting of cement. Professor R. C. Carpenter's experiments show that 1.5 per cent. of gypsum has the maximum retarding effect, greater or less quantities having less effect. Other cements would probably give somewhat different results. French cements, according to Candlot's experiments, take 2 to 4 per cent. of gypsum to produce the maximum effect. These small quantities increase the strength of the cement slightly except in sea water, in which the briquettes with gypsum ultimately disintegrate. The retarding effect of gypsum seems to be lost after the cement has stood some days or weeks. Hydrated lime added to this cement restores the power of the gypsum, though lime added to cement not containing gypsum has little retarding effect on the setting.

A weak solution of chloride of calcium in the water used in making mortar, say 10 grams per liter, retards the setting of the cement, while larger amounts, such as 100 to 400 grams per

liter, hasten the setting. It does not seem to injure the cement or concrete. Experiments in the Cornell University laboratory indicate that 1 per cent. of chloride of calcium, corresponding to 30 grams per liter in the French experiments, has the maximum effect, extending the time of final setting over 3.5 hours.

EFFLORESCENCE.

Efflorescence on concrete surfaces is caused by the carriage by moisture of soluble substances in the cement or in the aggregates to the surface, where the evaporation of the water leaves the substance until it is washed or brushed off. If there is too little water in the concrete when it is deposited, complete combination does not occur in the cement, the concrete is likely to be somewhat porous and subsequent moisture from any source has an opportunity to bring the soluble substances mentioned to the surface. When too much water is used it may separate the lime from the other ingredients in the cement to some extent and when it evaporates it leaves the concrete somewhat porous and brings soluble matters to the surface. Efflorescence is its own cure if a sufficient amount of the soluble matters is brought to the surface to close the pores and make the mass waterproof, but removal of the deposit prevents this action and the efflorescence will continue to some extent until the soluble matters are all brought out. Waterproofing a block will prevent efflorescence by keeping out the water which brings the soluble salts to the surface. Mr. Clifford Richardson recommends the addition of a small proportion of slag or some active form of silica to combine with the free alkali, but lays special stress on using exactly the proper amount of water in mixing the concrete.

The efflorescence can be removed by a wash of 1 part hydrochloric acid and 5 parts of water well scrubbed on and immediately washed off with a stream of water from hose. In Washington, D. C., this process applied to a bridge cost about 20 cents a square yard on flat work, but was 60 cents for the whole work, including balustrades.

In monolithic work efflorescence takes place on vertical or inclined surfaces most frequently at the plane of junction of old work with new. A slight skin of denser mortar forms on the upper surface during tamping, which makes a compara-

tively water-tight layer. Water seeping into concrete from the rear or from above works it way to the outer surface at this impervious layer and deposits the soluble materials, which it has brought with it, upon the surface of the concrete as it evaporates. If this impervious skin, which is very thin, is removed by brushing and washing with a little more vigor than is needed to remove loose material before depositing the new layer of concrete, the water getting into the wall will find its way farther down and may not get out until it gets below the surface on which its appearance is objectionable. Sloping these surfaces of division between layers so that the water will tend to flow to the back of the wall will aid in some cases.

WATERPROOFING CONCRETE.

Italian experiments show that the porosity of concrete depends on three classes of voids, those in the sand which are not completely filled with cement, those due to air adhering to the sand grains and those due to evaporation of excess of water used in mixing. However, porosity does not follow the same laws as permeability of the concrete and the conclusions regarding permeability of cement by water are as follows: Mortars of fine sand are less permeable than those with coarse sand; permeability decreases as proportion of cement increases and neat cement is the least permeable; concrete made with 700 pounds Portland cement,, 1 cu. yd. mixed sand and 1¼ cu. yds. of small gravel made into a cylinder with 2½-inch shell was impermeable under 13 feet head and barely permeable under 27 feet, while without the gravel the mortar was some what permeable under 13 feet and very easily so under 27 feet head. The concrete with the amount of cement increased to 1,150 pounds was impermeable under 40 feet head.

American experiments by Hyde and Smith showed that 1 to 1 mortars were impermeable under 80 pounds pressure per square inch, (184 feet) when 30 to 45 per cent. of the concrete aggregate. Some of the concretes with 1 to 2 mortars were impermeable but others were not. All others leaked under high pressure. The thickness of concrete was 5 inches and time of application of pressure 24 hours on all which showed no leak in 2 hours, with same result. Mixtures of 1:2:4 and 1:2½:4 well mixed and placed are practically impermeable.

but in extreme cases the mixture should probably be somewhat richer.

If it is desired to make leaner concretes or those not well compacted waterproof some of the following methods may give satisfaction:

Mr. Robert W. Lesley, in a discussion before the American Society of Engineers, states his conclusion that the best addition to cement mortars for making them impermeable is a reasonable proportion of slaked lime. If thoroughly hydrated the lime is safe, it slightly delays the setting of the cement, and it will effloresce to some extent, but the ultimate formation of the carbonate of lime closes the pores in the concrete and makes it impermeable permanently.

One form of preventing the passage of water through a concrete or brick wall is that of a thin coat, say ⅝-inch, of a mixture of Portland cement, sand and a chemical termed hydrolite. This coating can be applied to the inside of basement, pits and the like as well as of swimming pools and tanks and is said to give satisfaction by adhering to the wall even under 50 pounds of water pressure on the other side of the wall. A hard finish can be applied on the waterproof coat.

U. S. Government engineers have used Sylvester's process in fortification work. One specification prepares a wash of 1 pound concentrated lye, and 5 pounds of alum in 2 quarts of water, to one part of which is added 10 pounds of cement, dark color preferred. The wash should be applied on a cloudy day after the wall has been well wet with a hose. The solution must be kept well stirred after the cement is added.

For cistern work the usual wash is a simple cement grout applied with a brush in one or two coats, usually to a well-troweled surface. If the head of water is more than 10 feet, a coating of asphalt ¼ inch thick in addition will serve up to 60 feet head. Tanks and conduits receive a coat similar to a cement sidewalk wearing surface, which is well troweled and applied as wet as it can be to remain in place. Arch rings and spandrel walls of arches receive similar coats usually without so much attention to troweling.

When perfect water-tightness is required, however, this class of work receives a coat of asphalt which is mopped on the mor-

tar coat to a thickness of about 1/8 inch and again plastered with cement mortar before the concrete or filling above is deposited. Asphalt mastic is sometimes used with thickness of 1/2 inch, omitting the rich cement mortar. Silicate of soda is applied with a brush and forms a water proofing by filling the surface pores. Professor W. K. Hatt added silicate of soda to the water used in mixing the mortar, diminishing strength and permeability 50 per cent. It seems to be more satisfactory, therefore, to apply the silicate of soda with a brush.

Professor W. K. Hatt made a 5 per cent. solution of ground alum in water and a 7 per cent. solution of soap, used the alum solution in mixing mortar half as much as the usual percentage of water, then added the other half in the form of the soap solution. The resulting mortar of sand and cement has its permeability decreased one-half and strength is not affected. The Sylvester method of applying the alum and soap is apparently more satisfactory, though much more difficult.

Mr. Edward Cunningham added to the cement and sand one per cent. of powdered alum by weight and to the water one per cent. of yellow soap, the proportions of cement and sand being 1 to 2. Mortar without the additions was about 12 times as permeable as the treated mortar, the passage of water through the latter being through "pin holes" apparently due to carelessness in placing. The walls of the test vessels were 3/4 inch thick. A 1/4-inch plaster of similar nature on the inside of a clear water well rendered it water-tight. The materials required add about $1 to the cost of a cubic yard of concrete.

Liebold's (German) patent adds to 100 kilograms Portland cement clinker 300 grams of Japanese berry wax and 20 grams of caustic lime dissolved in 8 liters of boiling water thoroughly mixed and dried. The clinker is then ground in the usual way. Concrete made with this cement in proper proportions is said to be waterproof.

There are numerous secret preparations on the market for hastening the setting of cement and for making it waterproof, nearly all of which are probably composed of one or more of the substances here named or of chemicals which are ultimately detrimental to the strength or durability of the concrete.

Care must be taken in accepting such compositions without full knowledge of their nature and effects.

There are now on the market solutions of paraffine which are applied with brush and close the surface pores of concrete, thus preventing absorption of water and efflorescence.

Anhydrosol, lockpore, Szerelmey stone liquid, dehydratine, anhydrine, antihydrine, are names of some of the preparations on the market.

Almost complete impermeability can be attained by proper selection of sizes of grains of sand and stone, and proper proportions of cement. The principle on which this method is based is the reduction of the voids in the cement and stone to a minimum, and the complete filling of these voids with cement, with as little excess of cement as practicable. An excess of water seems to aid in producing the proper mixture and is preferred to a deficiency of water.

A pump room in San Francisco, 50 feet in diameter, with a thin reinforced concrete floor and walls of cement 5 feet thick at bottom and 2 feet at top, is waterproofed by a sheet of asphalt roofing felt with asphalt cemented joints laid on the sand under the floor and a cement coat of asphalt 1/8 inch thick on the outside of the concrete walls. It is tight under about 18 feet head.

Removal of portions of the old Park avenue tunnel north of the Grand Central station in New York city uncovered waterproofing of the tunnel masonry laid 33 years ago, which consisted of tarred felt and coal tar. It was in perfect condition.

EFFECT OF OIL ON CONCRETE.

Mr. James C. Hain has made some experiments on the effect of oil upon concrete which are not conclusive, but show very serious effects in some instances of animal oils in disintegrating cement mortar. These results were observed in some of the experiments with lard oil and with signal oil, which is a mixture of animal and mineral oils. Vegetable oils had less effect upon concrete and mineral oils, such as petroleum and its products, had but little effect. In some instances no effect was produced by any of the oils. Thus far, therefore, it is only possible to call attention to the fact that sometimes oils of certain kinds have very serious effects upon concrete. Mr.

Hain made a search for a coating to prevent the action of the oil but has not yet succeeded in finding it.

RETEMPERING CEMENT MORTAR.

It is a common belief among cement workers that cement mortar is improved by allowing it to take a partial set and then retempering it. Notwithstanding the fact that there are a few statements of results of tests which seem to bear this out, the weight of testimony is to the effect that this process is detrimental to the strength of the mortar. This is perhaps shown on the work by the fact that the retempered mortar sets more slowly than the fresh mortar. The following results of tests at the Manhattan Railway Company's power station during its construction, made by Thos. S. Clark, resident engineer, show the actual effect of retempering upon natural hydraulic cement mortar:

EFFECT OF RETEMPERING ROSENDALE CEMENT MORTARS.

Neat cement with 28 per cent. water.

Hours in Water.	Age in Days.	Tensile Strength not Retempered.	Llbs. per sq. in, Retempered After 60 Min.
3	1	139	27
24	7	166	64
24	14	180	80
24	28	219	94
24	56	322	180
Mortar 1 cement, 3 sand, 14 per cent water.			
24	28	39	31
24	56	73	59
24	112	113	56

The first two lines give averages of 20 to 43 tests; the other results are averages of 5 to 7 tests.

Portland cement sets more slowly but it will be injured in like manner by retempering after its first set has begun to show, probably for most brands within the second hour after mixing.

EFFECT OF FROST ON CONCRETE.

The effect of cold is to stop the setting of cement. Most cements set very slowly if at all below a ecrtain temperature, which is usually between 30 degrees and 40 degrees F. When the temperature is raised the cement sets, unless in the meantime the water has evaporated sufficiently to leave an insufficient quantity for the chemical action, so that the freezing

of work laid in cement mortar usually has the effect simply of delaying the hardening of the mass. If too much water is used in the mortar the expansion of the water in freezing may disintegrate the mortar by the mechanical action of the ice in forming. Either of these effects is most apparent near the surface of the mass of masonry, and often requires pointing up of the joints of brick or stone masonry while the remainder of the work will be found in good condition. Alternate freezing and thawing increases the danger of injury. Portland cement is seldom injured by freezing, but many natural cements are more or less injured, and mortar of natural cement is the more liable to disintegrate even under the best of conditions, if the temperature is long enough or often enough below freezing point before it has an opportunity to set. In a few instances some setting of mortar frozen for a long time has been observed, but as a rule the setting is delayed until the temperature again rises above freezing point.

The first method of aiding the setting of mortar which suggests itself is to delay the time of reaching the freezing point by heating the stone or brick, the sand, the cement and the water. The amount of heat required depends upon the temperature of the air and the rapidity with which the work can be done after heating stops. This method is seldom entirely satisfactory unless very quick-setting cements are used. Slow-setting cements will evidently give more trouble than those which set as quickly as can be permitted under the conditions of time necessary to get the mortar into the work after the water is added. Mortar should be made richer than for use at ordinary temepratures, say 1 to 1½ instead of 1 to 2, and other mixtures in the same proportion. As little water as possible should be used, although this will increase the probability of requiring pointing of joints or the crumbling of outer surfaces of concrete. It is frequently possible to delay freezing by covering the work with straw or even tarpaulins. If stable manure can be kept in place in sufficient quantities to keep up its fermentation, it is the most efficient material for covering, but one complaint of surface disintegration from its use has been reported in Municipal Engineering. Perhaps the most common method of prevent-

ing the freezing of mortar is the use of a solution of common salt for mixing. The usual rule is to add 1 per cent. of salt to the water for every degree of temperature below freezing, using the minimum temperature to which the masonry will be subjected for the computation. This amounts to about 1.3 pounds of salt per barrel of cement per degree below freezing. The cold delays the setting of the cement, but there is no mechanical action from freezing, and the results of this method are usually quite satisfactory, the pointing of joints being the only additional operation expected. It is evident that work to be placed upon concrete laid in freezing weather must be delayed until the setting of the cement makes the mass sufficiently stable to carry the weight. Laying of masonry, especially of massive stone masonry, in freezing weather is quite easy, but the placing of masses of concrete in exposed situations or of small sections of concrete is not so easy nor so certain of success.

In France some experiments have shown that 0.7 pound of carbonate of soda, dissolved in each gallon of luke warm water used in making mortars, will gain time in the setting of cement in cold weather. The amount mentioned corresponds to a temperature of about 14 degrees F., and the amount of the carbonate of soda may be doubled if necessary, or reduced. The increase in cost is about 20 cents a cubic yard of mortar.

Some experiments on the freezing of mortar at the Holyoke dam showed that freezing reduced the strength about 50 per cent. except in the case of quick-setting Portland cements, which were affected but little.

Buildings, and at Chaudiere Falls, Quebec, a dam, have been built under the protection of canvas or frame sheds in which the temperature was kept up by means of stoves.

CEMENT IN SEA WATER.

An investigation of the action of sea water upon cement, made by Mr. Le Chatelier upon rather meager data, leads him to the conclusions that the principal cause of decomposition of cements in sea water is the formation of supho-aluminate of lime, and that the presence of 4 per cent. of alumina in the cement in form capable of combinations sus-

ceptible to hydration is dangerous. Cements in which iron is substituted for alumina are better, the resistance of such cements to decomposition by sea water being much greater. Reduction in the amount of lime improves the cement in this respect, but at the expense of other qualities if too great. Silicious puzzolan seems to improve cement intended for use in sea water. Too much importance must not be given to this report until further experiments or observations are made.

STORAGE OF CEMENT.

Several of the specifications for cement in the preceding chapter give instructions for the storage of cement. The principal requirement of the storage room is dryness. Rain falling or driven by the wind must be kept from the packages and the floor must be high enough above the ground to insure that no water can be absorbed from it. Nearly all cements are improved by proper storage and it is a common requirement in English specifications that cements be spread on a floor in a perfectly dry warehouse and allowed to "aerate" or "cool" or "cure" for a fixed number of days. In America this curing is supposed to take place in the storage bins at the cement factory, but does not usually seem to be so necessary as with English cements. The addition of about 2 per cent. of gypsum is often made in grinding, one of the results of which is that the time of storage may be diminished.

The outer portion of cement in a package may sometimes harden somewhat from absorption of moisture from the air without injuring the cement in the interior. The hardened or lumpy cement should not be used without thorough test, though sometimes it does not seem to be injured. Cement in sacks is sometimes hardened by storing in high piles, the lower packages being compressed by the weight above, and this kind of lumps should not be mistaken for lumps formed by absorption of water.

COLORING AND PAINTING CONCRETE.

For coloring cement work mineral colors are generally used. Nearly all coloring matters reduce the strength of cement, but ultramarine in small quantities increases it. Red oxide of iron, if it contains sulphuric acid, may cause

swelling. Black and bluish gray are produced by using different quantities of lamp black or peroxide of manganese; red, by the best raw iron oxide; bright red, by caput mortuum (expensive); a cheaper red by venetian red; brown, by the best roasted iron oxide; buff, by ochre; blue, by ultramarine; bright blue, by prussian blue.

Cement manufacturers recommend the following quantities per 100 pounds of cement:

Black, 2 pounds excelsior carbon black.
Blue, 5 to 6 pounds ultramarine.
Brown, 6 pounds roasted iron oxide.
Gray, ½ pound lamp black.
Green, 6 pounds ultramarine.
Red, 6 to 10 pounds raw iron oxide.
Bright red, 6 pounds Pompeiian red.
Yellow or buff, 6 to 10 pounds yellow ochre.

It is said that unfading colored cement can be made by mixing with the raw materials before burning chromic oxide for green, oxide of copper for a blue-green, and equal parts of oxides of iron, manganese and cobalt for a black color. Such cements are not on the general market, however. Finely ground oxide of manganese added to the mortar will give a black color and not weaken the concrete. Venetian red and lampblack will fade.

White cements are often asked for. There is some difference in shade of Portland cements and puzzolan cements are usually the lightest. They are not satisfactory for greatly exposed work. An English patent makes a white cement by mixing one part of kaolin, a clay without iron, three to five parts of white chalk, and two to five per cent. of gypsum, or three to five per cent. of magnesium chloride. The mixture is burned as any other cement is burned. The resulting cement would probably not stand severe exposure to the weather. Lafarge, a French "grappier" cement is very light colored. The use of white marble dust in place of sand and puzzolan or lighter cements produces the best results yet obtained. Sulphate of barium, oxide of zinc and sulphate of lead produce a grayish white color, but their permanence is not guaranteed.

Portland cement concrete must be thoroughly set before

painting, and a year's age is advisable. The durability of the paint will be increased by first brushing the concrete surface with a solution of one part sulphuric acid in 100 parts of water and allowing it to dry. A coating of one part silicate of soda in three or four parts of water applied two or three times, with a washing with water between, is good as preparation for oil paint.

MOLDS AND FORMS.

With reference to forms or molds Mr. W. A. Rogers says that their construction for the ordinary low abutment or culvert wall is a comparatively simple matter. He uses 4x6-inch or 6x6-inch uprights with 2-inch plank surfaced on one side and two edges, lightly nailed against the posts to form the faces of the wall. Ten-inch width of plank is convenient for a uniform size. Front and back faces of form are held together by rods through opposite posts, and the front is usually braced to stakes driven in the ground, or to piles. For low culverts and abutments one rod at bottom and top of each set of posts is sufficient, the bottom rod being left in and the top rod being above the upper surface of the finished concrete. If coming in the concrete, they are cut off at the surface of the concrete and left in. Sometimes each form can be braced in position without the cross rods for low work. The face planks must be placed level and for specially smooth surface the planks are surfaced on both sides to a specified thickness. The posts are spaced 5 feet 4 inches or 4 feet centers where 16-foot planks are used. For high piers posts 6x8 or 8x8 inches are used or two 3-inch planks with 1-inch blocks between them, placed so that the face planks are nailed against the edges and the rods passed through the space between planks to nuts and washer against the outer edge. For arches the lagging is beveled to give a fairly tight upper surface. A 1-4 round is tacked on each square turn of the forms to give a rounded corner in the finished wall

If 1-inch sheeting is used the uprights should not be more than 2 feet apart.

Mr. C. R. Neher offers the following in the paper referred to on page 135:

The preparation of forms calls for considerable ingenuity and every contract requires special study, to the end that smooth surfaces be left, with unbroken corners, that the swell

ing of the wood does not rupture the concrete or leave distorted surfaces; and that the forms be so designed as to be used several times, and readily set up and taken down and later on devoted to other uses. As the charge for forms against the concrete can seldom be kept below 50 cents per cubic yard for heavy work, there is always an opportunity for the ingenuity of the designer, as few rules can be laid down for his guidance.

The use of matched or tongue-and-grooved stuff is not desirable, as concrete fills in the openings and there is no opportunity to expand from moisture. Unmatched boards dry apart and let the water in the concrete leak out, carrying with it some of the cement. Later on they swell and buckle and, if used as interior forms, burst the concrete. The best way devised so far is to bevel one edge of the boards, using narrow stuff, not to exceed 6 inches. The sharp edge of the bevel, lying against the square edge of the adjoining board, allows the edge to crush when swelling and closes up the joint, preventing buckling.

A coat of soft soap, before filling the forms, prevents the concrete from adhering to the forms, which should always be scraped and brushed with a steel wire brush when taken down.

Square corners should be avoided, as they readily chip off, and where used as interior forms for recesses or cellular construction, a fillet should always be placed in the corners.

Concrete can often be saved by introducing cells in the mass. These are formed either by cheap hemlock boxes, which can be left in the work, or by collapsible boxes which can be withdrawn and used over again. Where weight is desirable, one-man stone can be rammed in the heart of the mass, reducing the cost very materially.

Where, for economy in handling and other reasons, it is desirable to dump the concrete from a considerable height, some precaution should be taken to avoid having the coarse aggregates separate from the rest of the mass. This can be accomplished in several ways—either by chains loosely stretched at intervals across a chute or by shelves extending part way across the chute at an incline, so as to deposit on a corresponding shelf on the opposite side, so alternating for the length of the chute. Either of these methods is a direct benefit, as it more thoroughly mixes the concrete.

The molds on the piers of the approaches to the Mingo bridge across the Ohio river near Mingo island and the methods of handling them present some interesting features. The piers were built in rectangular courses each 8 feet high, except where other heights were necessary for closure. Each course of each pier was separately deposited in place, the concrete being mixed

wet and filled into the form in less than two hours. Molds were used several times over, so that not more than 20 per cent. of the timber required to build up molds for all the piers was actually used.

A mold was composed of three courses of siding each 2.66 feet high made with 2-inch horizontal boards fastened together by cleats on the outside. In the largest bottom forms these boards were 20 feet long and in the smallest forms for top courses they were 8 feet long. The boards were 6 and 8 inches wide, tongued and grooved and planed on both sides. The cleats were 2 by 8 inches in cross section and spaced 4 feet or less apart. At the ends the cleats were 2 by 4 or 4 by 4 and served as stops in the corner joints in assembling the mold. Similar parts of courses were interchangeable and could be cut off at one end and made ready for the next course above by replacing the end cleats. The three courses forming a mold 8 feet high were placed at the same time in a fixed order of sections, and they were bolted at each corner to two 4-inch by 4-inch by 8-foot vertical posts, which bound the courses together. Two vertical reaction beams were placed on each side of the form. These beams were made of two 2 by 10-inch planks, small dimension bearing on the vertical cleats, the planks being kept 1 inch apart by wooden fillers. The reaction beams were 18 feet long, thus fully covering two sections of concrete. On the ends of the pier these beams were spaced 4 feet apart and on the sides they were 6 feet apart. The beams on opposite sides were bolted together by ⅝-inch rods, 8 feet apart vertically, each beam thus having three such rods. As they crossed the mold they left a central free space 6 by 4 feet for the passage of the concrete bucket. The rods were surrounded by light tin tubes 1 inch in diameter, which were left in the concrete and filled with grout after the rods had been withdrawn. This bracing was found to be not quite sufficient, as the wet concrete used deflected the 2-inch planks of the forms too much if their span was more than 4 feet. The 6-foot spaces on the sides of the piers were therefore braced by an intermediate vertical reaction beam, the strain of which was carried by two horizontal transverse beams to the rods on each side of the 6-foot space spanned by them.

After the concrete in a mold had set, the mold below was taken off and reset for a new section, the order of removal and resetting of pieces being: First the long vertical reaction beams, which were moved up one-half their length and reset on the bolts at the bottom of the section of concrete just set and those on the top of the section, the third set of bolts being placed at the top of the beams, 8 feet above the concrete in place; second, unbolting of lower courses of mold and removal to new position above, fillers being used and panels being cut as necessary to fit the reduction in size of pier.

J. C. Van Natta has patented a clamp for a wall mold, consisting of two malleable iron rods to project through the form, and each having attached a cam. A piece of wire is hooked over each of the projecting ends and the cams are turned until the tension on the wire brings the two sides of the form to the proper bearing and distance apart. The wire tie is embedded in the concrete, and when the form is ready to remove the cams are released and the rods of the clamps are pulled out of the concrete. The small hole left is filled with cement.

The Chicago, Milwaukee & St. Paul railroad uses a similar device designed by J. C. Hain, which consists of two castings each having a threaded core and two rounded projections, which hold in place wires wound round them. One of these castings is screwed on a rod on each side of the wall and these rods bear on straining pieces on the outside of the form. The rods and castings being in place and the wire wound round the two castings to connect them, the nuts on the rods are tightened up until they bring the forms into proper position and bearing. When the concrete has been deposited and has set and the forms are to be removed, the rods are unscrewed from the castings and the castings and wire are left in the concrete. The small holes left on withdrawing the rods may be filled with cement.

Shute and Henschen have patented a movable form for molding concrete walls, using slotted gauge plates with finger and gauge bars for holding the two sides together. A sleeve permits the removal of these bars after the concrete has set, and the sleeve can also be removed. The same forms can thus be used

for successive courses in the same wall and the work can proceed continuously.

Farrell's clamps are in use for holding forms together during construction and reduce the disturbance of the wall in removing forms to a minimum.

Robert R. Evans, city engineer of Haverhill, Mass., describes a movable form for concrete sewers used by him as follows:

A plate of steel 1/4 inch thick and 6 feet 2 inches long, was bent to a semi-cylinder with an inside radius of 18 inches, and the sides extended on a tangent to the curve, about 6 inches above the plane of the horizontal diameter. The front open end was stiffened by a curved 3-inch angle iron riveted to it, with a horizontal angle iron riveted across its upper ends, while the rear open end was held apart by a 2x1/2-inch iron bent down at the ends, and riveted to the inside of the steel plate near its top edge. Along the inside of the shell thus formed, longitudinal 1 1/2-inch angle irons were riveted with the horizontal leg up, and 1 1/2 inch above the horizontal diameter. These angle irons served as tracks, or ways, for the support of the inside, or core, forms. The inside forms were made in 3-foot lengths, and consisted of two ribs made of 2-inch plank, to which narrow strips of wood were nailed, forming a semi-cylinder, which was covered with sheet iron.

To facilitate lifting these forms out of the concrete, their upper edges were spread about 1/4 inch from a true semi-circle. Along the inside bottom of each form, a 4x6 inch timber extended from end to end, passing through the ribs, which were fastened to it, and a projection on the top of this timber, at the rear end of the form, prevented the front end of the following form from lifting above it.

When all the forms were in place this timber formed a continuous column for their entire length, against which the jack reacted in forcing ahead the outer form. Across the top of each rib a 3x3-inch oak timber was fastened, projecting 6 inches beyond the sides of the inner form, at such a height that, when this inner form was dropped into the steel shell, it was held suspended concentrically within the outer form, leaving an annular space of 6 inches in which to place the concrete. It will be readily seen that the inner form was then free to slide out at the rear end of the outer form, while still retaining its concentric position in relation to it.

A partition of 3-inch plank fastened to the back of the curved angle iron in the forward end of the outer form, to which was bolted the base of an ordinary track jack, and a second, movable partition to receive the thrust of the head of the jack, and

made of two layers of 3-inch plank, fitting loosely in the outer form, and hung from a cross bar sliding on the longitudinal ways, completed the essential parts of the outfit.

In use the outer form was placed in the trench which has been excavated to the proper depth, and set to the line and grade. One of the inner forms was then dropped in, resting on the ways, and the movable partition brought against the forward end of this inner form, and held there by slightly tightening the jack. Concrete was then deposited in the annular space between the two forms, and rammed by a curved iron rammer. The jack was then brought into action and, with its base bolted, as previously stated, to the forward partition fixed in the outer form, and its head reacting against the movable partition which in turn reacted against the ends of the forward inner form and of the newly made concrete section, forced the outer form ahead.

The Collapsible Centering Company has a center for sewer and conduit work made in sections, the lower sections carrying a track on which the upper sections can be carried forward when ready for removal and setting ahead.

Thomas A. Burrows has invented a collapsible steel form for any cross section of sewer, the sections of the form being forced to place and released by sleeve nuts.

DEPOSITING CONCRETE UNDER WATER.

During the construction of the Holyoke dam in Massachusetts an experiment was made to illustrate the effect of dumping concrete into place under water. A batch of concrete was mixed, 1 part cement, 2¼ parts sand and 5 parts broken stone, as required on the work, and dropped before setting into a pail of water. At the end of 12 months it was examined. About ¾ inch of nearly neat cement, hard set, was found as a top layer, then about 2½ inches of sand, with enough cement to hold together and a few stones, then 2 to 3 inches of sand and stone nearly separate and perfectly clean, with no adhesion whatever. This indicates that separation of materials dropped into place through water is too serious to be neglected.

On a large bridge at Ottawa, Canada, a concrete "kibble" was used for dumping concrete in the foundation under water, which was found very satisfactory. It is a steel bucket, wedge shaped and hung by six chains to the four corners and the hinges at the middles of the short sides, which meet in a ring

above the center of the bucket by which it is hung from the operating cable. The box is filled with concrete and the top covered with a canvas securely tied, lowered to the place of deposit and the latch of the bottom tripped, when the long sides swing on the hinges mentioned, enough to let the concrete slide out. The wedge shape causes little disturbance to the water in passing through and the batch of concrete is deposited with a minimum of unprotected movement through the water. Tests for wash were made by dropping the filled kibble 60 feet through the water at the usual speed and again elevating it to the surface and depositing the concrete in barrels on the surface, and also by depositing it in a box 8 feet under the surface, where it was obliged to drop the 3 feet of depth of the box through the water, a very severe test. The first test was satisfactory, an excellent core being obtained with a diamond drill. The second test gave no core, but the walls of the drill hole stood hard and firm.

In building the pier at Superior Entry, Wis., the concrete was deposited in molds under water, by using buckets with drop bottoms. Each bucket had two canvas covers 3 by 4 feet in size, weighted with 110 pieces of lead each 3 by 1 by 1-16 inch. One was fastened on each side of the top of the bucket, and when the bucket was filled with concrete they were folded over it, thus effectually preventing wash of the concrete as the bucket descended through the water, discoloration of the water being seldom seen during the lowering of the bucket. The concrete was mixed quite wet, and when the bottom latch was tripped it slid out of the bucket and into its place easily and quickly.

At the Nussdorf lock, Vienna, Austria, three trolleys were run over the lock, the three covering the entire area. Each trolley carried a vertical tube which was telescopic, and thus could be shortened as the work progressed. Three chutes on each car made delivery of concrete to the tube convenient, from dump cars running on service tracks.

MIXING CONCRETE BY HAND.

The specifications in the next chapter give instructions regarding mixing of concrete. The important points are careful measurement and thorough mixture, dry and wet. Specifica-

tions are often not definite in regard to the method of determining the exact amounts of material required. Usually the cement and sand are mixed dry and the stone or gravel and water is then added, practice varying as to order of doing this. The gravel or stone is occasionally added dry and water then added in a central basin formed in the mass or by hose, sprinkler or bucket, as the mass is turned over. More frequently the water is added to the mortar and it is then thrown over the stone and turned over with it or the stone is dumped into the mortar and the mass then turned over until it is thoroughly mixed according to the specifications in use, there being considerable difference in requirements as to methods of mixing and number of times turning over, dry and wet, as the specifications referred to will show.

Perhaps the most common method, where accuracy in proportions is required, is to deposit the stone or gravel in a measuring box, preferably bottomless, so that it can be removed readily, to a fixed and uniform depth, then put in a layer of sand of proportionate thickness and complete with a layer of cement. This mass is then turned over dry with shovels by four men working at the ends and turning out. It is then turned back again toward the center, and this is repeated as often as the specifications require. The water is then added, partly in a crater cut in the top of the rounded pile of concrete and partly by sprinkler, while the men are again turning the mass over from and towards the center until it is thoroughly mixed.

CONCRETE MIXERS.

Concrete is more quickly mixed by machine and more thoroughly. A smaller amount of cement, say ten per cent. can, therefore, be used to secure the same strength of concrete. The uniformity of the concrete makes expansion and contraction of all parts of the mass the same under the same conditions, thus preventing disintegration on this account.

The simplest concrete mixer is the portable gravity mixer, which is a simple chute of rectangular cross section, provided with deflecting plates arranged alternately on two opposite sides of the tube and also perhaps with pins project-

ing into the path of the materials. The materials are deposited in layers on measuring platforms or boxes and shoveled into the chute, or may be discharged into it by tipping the measuring boxes. Water may be added with the other materials or, as in one machine, may be sprayed upon the other materials as they pass through the chute, the rate of delivery of the water being under the control of the man at the delivery end. The mixed concrete is received in carts or barrows and is ready for deposit in its place upon the work. With proper care in shoveling or discharging the materials into the chute, and a careful man in control of the water, very excellent results are obtained. Another gravity mixer consists of four hoppers each of which receives the concrete ingredients in layers, cement at bottom, then sand, then stone. They are dumped through chutes into a single large hopper below and thence as desired to a second large hopper and from this to carts.

Another simple form of mixer which is also continuous in its action is a screw-conveyor in a box of proper form, the materials being dumped in at one end by shovel or tip, as in the case of the gravity mixer, and discharged at will from the other end. In some cases two or more of these mixing troughs are so set that the first will discharge into the second, and so on, and the mixtures of cement and sand, of water and of stone or other aggregate can be made separately or in any form desired. The water is usually applied by hose in the mixer of cement and sand, if more than one is used, and if the delivery of materials is continuous and uniform can be automatic. Practically, the hose nozzle must usually be in the hands of a man or boy with some experience. There is a slight opportunity to correct errors in discharge of materials into the machine by delaying delivery at the outlet. Power, from electric motor, gas or steam engine or other motor is necessary to run the machine. Arms on an axis, so formed as to move the material toward one end of the machine, take the place of the screw conveyor in one design.

There are many styles of batch mixers, into which a given quantity of the materials is discharged, the mixing performed and the concrete discharged. These are under per-

fect control, and any desired amount of mixing can be given each batch. Several of the designs are cylinders or double inverted truncated cones, with deflecting blades, so arranged that materials deposited in one end by hopper and tube at the axis of the machine, are gradually moved toward the other end of the machine while being turned over by the revolution of the cylinder on its axis. In one machine the batch is dumped from the discharge end without stopping the machine, so that it is practically continuous in its action, the barrow full of materials dumped in at one end being dropped out mixed at the other, and one batch following another as rapidly as the barrows can be wheeled up and tipped at one end and filled and wheeled away at the other. An addition of bins with automatic measuring devices for depositing materials in the cylinder makes an automatic and continuously acting batch mixer, which, at some expenditure of power, will mix the concrete with less manual labor if properly supervised by expert machinists. In another design the cylinder or double cone is tipped, at will, to dump the mixture into the cart.

Still another batch mixer is a trough with a series of arms set on a revolving axis, which turns over the materials deposited in the box until they are thoroughly mixed, when the bottom of the box is opened and the mixture dumped through a hopper into cart or barrow beneath. Some of this class have two such sets of revolving arms meshing together on their upward turn.

Most of the batch mixers require power from gas, gasoline or steam engine or electric motor, though some of the smaller and simpler machines can be run by hand. A gearing for use with horse power, one, two or four horses, as desired, is furnished by some manufacturers of machines. A batch mixer for use on street work, or in places where a horse can be driven, is composed of a cylinder set on an axle supported on two wheels. A cover opens to let the materials in, the cylinder turns while the horse is drawing the cart from the material supply to the place of deposit, where it opens and drops the mixture.

A cube hung on trunnions at two opposite corners is a thor-

ough mixer of materials without the necessity of guides or arms so that the chance for sticking of concrete to the machine is reduced to a minimum, the inside of the box being smooth and the passage of materials unimpeded. This is a batch mixer and water may be introduced in exactly measured quantities through the hollow axis.

The revolving pan mixer consists of an open circular revolving pan with plows on a fixed axis which stir up the materials as they are brought round by the pan. The mixture is dumped through trap doors in the bottom.

One form of automatic concrete mixer measures the proportions of materials, the cement, sand and stone being deposited in hoppers from which they are fed in fixed proportions by means of spiral conveyors to buckets on an endless chain elevator which discharge into one end of a drum, where the dry mixing is performed by means of steel paddles, which thrust the mixture to the other end, where a spray of water is applied. proportioned to the speed of operation of the machine. The wet mixture is then discharged into barrows or conveyors. This machine is continuous in its action.

Another automatic machine is all contained in a single cylinder and a hopper with as many divisions in use as there are materials to mix for the concrete. Buckets on the outside of the cylinder pick up the materials from a trough at the bottom of the hopper, are struck off level as they rise and discharge at the top of the revolving cylinder upon deflectors inside the cylinder, which mixes the materials dry as they are moved on by the deflectors. Water is added through the axis of the machine and the final wet mixture is discharged into barrows by means of a chute which receives it near the top of the cylinder from the last deflector. The chute can be tipped to stop the discharge of the concrete temporarily.

One machine has a traveling belt on which the wet mixture is deposited. The belt runs to the end of a boom which can be revolved through an angle of several degrees. The concrete drops off the end of the boom and, when the machine is used for street work, can be leveled off and tamped with a minimum of handling. The machine can also be fitted with apparatus

for hauling it forward slowly as the sheet of concrete is completed.

Since the establishment of the cement block industry there has been a demand for small mixers run by horse or hand power, or small gas, gasoline or electric motor. Several of these machines using the same principles as those described above are now on the market.

In a recent report of the Chief of Engineers, U. S. Army, is a description by Clarence Coleman of a device for supplying a fixed quantity of water to a concrete mixer. It is a barrel fitted with a 2½-inch inlet pipe, on the side near the bottom, a 2-inch outlet pipe in the bottom movable by means of a lever to vary the point of taking the discharge from the barrel, and a ¾-inch vent pipe in the top, extending up to the level of the surface of the water in the reservoir from which the water is drawn. The outlet pipe slides in a larger pipe set in the bottom of the barrel and has a valve to stop the discharge of water at will. The valves on the outlet and inlet pipes are operated by the same rod, so that one is closed while the other is open. The amount of water to be discharged for each batch of concrete being known, the top of the 2-inch pipe is set so that this amount will be discharged through it from the full barrel when the outlet valve is opened, any water below the level of the top of the pipe remaining in the barrel. A weight keeps the inlet valve open and the outlet valve closed and water runs in until it reaches in the vent pipe the level of water in the reservoir. When the water is to be added to a batch of concrete, the operator pulls the valve rod, opening the outlet and closing the inlet. When the water has run out, he lets go the rod and the weight sets the valves for filling the barrel again.

SPECIFICATIONS FOR THE USE OF CEMENT

A number of sample specifications for the use of cement will be given in this chapter. The list could be very largely increased without entirely covering all the corners of the field, but it is believed that enough forms for all the principal kinds of work have been given to make it possible to determine the average specifications for good work which will conform to the standards of good work which are here presented.

Special uses, such as statuary, tiling, etc., and its use in large work requiring special study and special machinery are not considered, as the space at command is more than full of the requirements for uses which are general in their character. It is not possible to follow any single program in arranging these specifications, but they will be found to be grouped as nearly as possible according to similarity of use or of composition of material, and the index will serve to locate any particular specification which is desired.

EXTRACTS FROM SPECIFICATIONS OF ILLINOIS CENTRAL RAILWAY FOR CONCRETE WORK.

Concrete materials are specified as follows:

Crushed Limestone.—This shall be made by crushing tough, hard, clean limestone and screening same through 2-inch meshes or holes. The engineer or inspector in charge shall reject crushed limestone which may have any of the following defects: A, containing more than 1 per cent. of earthy or clayey matter; B, more than 20 per cent. of fine stone or stone dust, less than ½ inch in size; C, more than 5 per cent. of soft or rotten limestone which can be crushed or powdered up in the fingers; D, more than 10 per cent. of flat stones larger than 2 inches in greatest dimensions; E, more than 15 per cent. of crushed stone larger than specified (passing through a 2-inch mesh), unless there be an equal amount of fine material less than ½ inch size; F, if any of the five classes of defective stone above named can be modified by mixing with additional material or by breaking large stone by hand, its use may be permitted under the direction of the engineer or inspector in charge; G, the use of clean gravel in place of not more than half of the specified amount of crushed

limestone may be permitted at the option of the chief engineer, or his authorized representative; but the work shall be done under such special instructions as shall be given in each individual case, depending on the quality of the gravel used and other existing conditions.

Crushed Granite.—This shall generally be used of two sizes; a fine crushed granite, to be used as a substitute for sand, and a coarser size, particles of which are not larger than ¾ inch in greatest dimensions, and to be used as a substitute for crushed limestone in making bridge seats, pedestal stones, etc. All crushed granite shall be clean, entirely free from dust and earthy or clayey matter, and each grade shall be of practically uniform size. This material shall always be handled on platforms or plank, or in some way kept entirely free from admixture of earth, sand, etc.

Sand.—This shall consist of clean, sharp sand ("pit" or "bank" sand being preferred), and sand shall not be rejected if containing occasionally pieces of small gravel. A sand is preferred which will not pass through a sieve having 30 meshes to the inch. Sand shall be free from earth or alluvial matter; and, when tested by stirring with water or by rubbing in the hands, shall not show the existence of more than 0.5 per cent. of loam, clay or earth. No sand shall be used for the outside finish of any concrete which contains small particles of coal or lignite, although sand of this character may be accepted for foundation concrete, or for the interior portion of any heavy piece of concrete work.

Cement.—This shall in all cases be approved by the engineer of bridges, and the inspector in charge of the work shall receive a written approval before permitting concrete to be made from any cement delivered. Where possible, cement shall be delivered in time to have samples properly taken and sent to the office of the engineer of bridges, for making the usual one-day and seven-day tests of neat cement. Contractors shall provide store-houses at the site of the several pieces of work in which to unload and store cement. Cement which is delivered on board cars must be unloaded promptly and stored in such warehouse, and the cars returned to the company's service. In no case will it be permitted to retain box cars on the work for the storage of cement. Cars which may be so held shall be charged to the contractors at the rate of one dollar ($1.00) per day for each day after the second day so held not unloaded. Contractors shall be responsible for the proper care of this cement after it has been received and stored, and any cement injured through carelessness or neglect shall be rejected promptly by the inspector in charge. No

brand of cement shall be used in any concrete work which has not been accepted in writing by the engineer of bridges, such acceptance to be based upon regular tests, where possible. The inspector shall from time to time, make small pats of pure cement, and of cement mixed with sand, to satisfy himself that the cement actually used is of uniform character, and has not been injured by exposure to weather or in any other way, and may reject any cement which is wet or lumpy, or which fails to set properly in sample pats, and the contractor shall remove the same promptly from the work.

Natural Cement Concrete.—This may be used where foundations are entirely submerged below low-water mark or where there is no risk of the same being exposed to the action of the weather by cutting away the surrounding earth. It, however, shall be used only where a firm and uniform foundation is found to exist after excavations are completed. In all cases where foundations are liable to be exposed to the action of the water, or where the material in the bottom of excavations is soft or of unequal firmness, Portland cement concrete must be employed for foundation work.

The natural cement concrete shall usually be made in the proportions (by measure) of 1 part of approved cement to 2 parts of sand and 5 parts of crushed stone, all of character as above specified. For Portland cement concrete foundations 1 part of approved cement, 3 parts of sand and 6 parts of crushed stone may be used. Wherever in the judgment of the engineer or inspector in charge of the work, a stronger concrete is required than is above specified, the proportions of sand and crushed stone employed may be reduced, a natural cement concrete of 1, 2 and 4, and a Portland cement concrete of 1, 2 and 5 being substituted for those above specified.

Portland Cement Concrete.—Concrete for the bodies of piers and abutments, for all wing-walls for same, and for the bench walls of arch culverts shall generally be made in the proportions (by measure) of 1 part of cement, 2½ parts of sand and 6 parts of crushed stone. Where special strength may be required for any of this work, concrete in the proportions of 1, 2 and 5 may be used; but all such cases shall be submitted to the judgment of the engineer of bridges, before any change from the usual specifications is to be allowed.

For arch rings of arch culverts and for parapet headwalls and copings to same, Portland cement concrete, in proportions of 1, 2 and 5 shall generally be used. Concrete of these proportions shall also generally be used for parapet walls behind bridge seats of piers or abutments, and for the finished copings (if used) on wing-walls of concrete abutments,

also for arch work in combination with I-beams or in combination with iron work for transverse loading.

Bridge seats of piers and abutments and copings of concrete masonry which are to carry pedestals for girders or longer spans of iron work, shall generally be made of crushed granite and Portland cement, in the proportion (by measure) of 1 part of approved cement, 2 parts of fine granite screenings and 3 parts of coarser granite screenings, the larger of which shall not exceed ¾ inch in greatest dimension.

Mixing Concrete.—All concrete must be mixed on substantial platforms of plank or boards securely fastened together, so that the various materials of the concrete can be kept entirely free from admixture of foreign matter. Hand-mixed concrete shall not be made in batches of more than one yard in each batch. The proper amount of the several kinds of material shall be measured in some way which is entirely satisfactory to the engineer or inspector in charge of the work, so that they may be satisfied that the requisite proportions of each kind of material are delivered for each batch of concrete. Satisfactory methods of measurement will be the use of headless and bottomless barrels for measuring sand and broken stone; the use of boxes into which the sand and stone may be cast and leveled off (the boxes then being removed), or the use of square and uniform sized wheelbarrows, expressly designed for this purpose. The measurement of sand and broken stone in the ordinary shallow, round bottom wheelbarrows will not be considered satisfactory, and shall not be permitted.

The detail of mixing concrete by hand shall be generally as follows: The proper amount of sand shall be measured out and spread upon the concrete platform, and the proper amount of cement shall be delivered and spread upon the same; the sand and cement shall be turned over dry, either by means of shovels or hoes, until they are evenly mixed. They shall then be wet and made into a rather thin mortar, and shall then again be spread into a uniform and thin layer upon the concrete platform. The proper amount of concrete stone (the same having been previously drenched with water) shall be spread upon the mortar, and the whole shall be turned over at least twice, either by shovels or hoes, before it is loaded into wheelbarrows, or in any other way taken to be placed in the work. In wetting the mixture of sand and cement to make the mortar, and in wetting the subsequent mixture of stone, sand and cement (if necessary), a spray or sprinkler shall be used. The water must not be dashed upon the mass in buckets or large quantities, or by means of

a jet. The inspector shall insist that the resultant mixture of sand, cement and stone be as nearly as possible uniform in character, the mortar being equally distributed throughout the mass of the stone. The inspector shall also see that the mixture is neither too wet nor too dry. It should be of such a consistency that, when thoroughly rammed, it will quake slightly, but it should not be thin enough to quake in the barrow, or before ramming. The inspector shall satisfy himself that the proper proportions of cement, sand and stone are used, checking from day to day or from time to time with the total amount of each which is received and used.

Machine-mixed concrete shall be made of the same general consistency as the hand-mixed concrete above specified. Proper precautions shall be taken to see that the requisite proportions of the different ingredients are used. If machines are used which are not provided with devices to deliver each of them, the process of making the concrete shall generally be as follows: The proper amount of sand, cement and stone for a batch not to exceed one yard of concrete shall be delivered on the platform and roughly mixed together so that when the dry mass is cut down and delivered to the mixer by means of shovels proper amounts of each of the ingredients are handled in each shovelful.

It will not be regarded as a satisfactory process to deliver crushed stone, sand and cement at random to the mixer without taking some special means, as above described, to insure the delivery of the proper quantities of each ingredient as nearly as may be simultaneously.

Molds.—Molds of substantial character shall be made in which to construct all concrete work. The material for these molds shall be furnished by the contractor, and the expense of furnishing this material and of constructing and removing all molds shall be covered in the price per yard paid to the contractor for the several classes of concrete work called for. The face of the mold next to the concrete shall be finished smooth, planks which are dressed at least on one side being employed for this purpose. Material for the molds shall be of sufficient strength so that they shall be practically unyielding during the process of filling, tamping, etc. The different gether, if desired, by tie rods or wires extending through the parts of the frame work for the mold may be fastened to-concrete. If tie rods are used they shall be so designed that no iron work will be left outside of the concrete or within less than 2 inches from the face of the same when the molds are removed. This may be accomplished by sleeve nut connections which will permit the removal of the projecting ends of

bolts or rods, etc., leaving only small holes in the concrete which can be stopped with pointing mortar after removing the molds. Another satisfactory method of bracing molds is to construct them with cross ties between the front and back, these ties to be placed at frequent intervals above the lower portion of the mold and to be removed as the concrete is built up, the studding out of which the molds are constructed being sufficiently long to extend above the top of the finished masonry, and at least one set of ties being used above this level. In general 2-inch plank, sized to approximately 1¾ inches thickness, shall be used for the facing of all molds, and studding for frames shall be placed at intervals of not more than 4 feet. The planking forming the lining of the molds shall invariably be fastened to the studding in perfectly horizontal lines, the ends of these planks shall be neatly butted against each other, and the inner surface of the mold shall be as nearly as possible perfectly smooth, without crevices or offsets between the sides or ends of adjacent planks. Where planks are used a second time they shall be thoroughly cleaned, and, if necessary, the sides and ends shall be freshly jointed so as to make a perfectly smooth finish to the concrete.

The molds for projecting copings, bridge seats, parapet walls and all finished work shall be constructed in a first-class, workmanlike manner, and shall be thoroughly braced and tied together, dressed surfaces only being exposed to the contact of concrete, and these surfaces shall be soaped or oiled if necessary, so as to make a smoothly finished piece of work. The top surfaces of all bridge seats, parapets, etc., shall be made perfectly level, unless otherwise provided in the plans, and shall be finished with long, straight edges, and all beveled surfaces or washes shall be constructed in a true and uniform manner. Special care shall be taken in the construction of the vertical angles of the masonry, and where I-beams or other iron work are not used in the same, small wooden strips shall be set in the corners of the mold, so as to cut off the corners at an angle of 45 degrees, leaving a beveled face about 1½ to 2 inches wide, instead of a right-angled corner.

Where wing walls are called for which have slopes corresponding to the angle of repose of earth embankments, these slopes shall be finished in straight lines and surfaces, the mold for such wing walls and slopes being constructed with its top at the proper slope, so that the concrete work on the slope may be finished in short sections, say from 3 to 4 feet in length, and bonded into the concrete of the horizontal sections before the same shall be set, each short section of

sloped surface being grooved with a cross line separating it from adjacent sections. It will not be permitted to finish the top surface of such sloped wing walls by plastering fresh concrete upon the top of concrete which has already set, but the finished work must be made each day as the horizontal layers are carried up, to accomplish which the mold must be constructed complete at the outset; or, if the wing wall is very high, short sections of the mold, including the form for the slopes, must be completed as the horizontal planking is put in place.

Foundation concrete may be put into excavations without the use of molds, provided the sides of the excavations are reasonably true and the material is sufficiently firm, so that the concrete may be rammed thoroughly without yielding to the adjacent earth. Where a cheaper kind of concrete is used for foundation work, the top of the same shall be finished smooth and level, the corners and edges being thoroughly rammed and compacted, and the whole surface filled full of mortar. It will not be satisfactory to leave a honey-combed surface or one on which a lot of loose concrete is left scattered about.

It is not expected that the surface of such foundation work shall be accurately leveled unless cut-stone masonry is to be built upon it, but the inspector must insist that that portion of such foundation concrete which projects outside of the masonry which is to be built upon the foundation must be thoroughly rammed and compacted, and must have a finished surface. If this can not be accomplished without constructing a mold for the upper portion of such foundation, the contractor shall furnish material and construct such mold, and the cost of the same shall be included in the price of the foundation concrete.

Iron rails to be furnished by the railroad company shall be laid and embedded in such manner as may be specified in such foundation concrete as in the opinion of the engineer of bridges needs such strengthening, and no extra charge, except the actual cost of handling the same, shall be made by the contractor for such work, but the volume of such iron shall be estimated as concrete.

Where I-beams are to be placed in the angles of concrete piers as a protection against ice, drift, etc., these shall be set up and securely held in position so that they will extend 1 foot or more into the foundation concrete. The planking of molds shall be fitted carefully to the projecting angle of these I-beams and small fillets of wood shall be fitted in between the inner faces of the mold and the rounded edges of the I-beam flanges so that no sharp projecting angle of concrete will be formed as the work is constructed.

These fillets may be made in short pieces and fastened neatly into the mold as the layers of concrete are carried up. Such I-beams will generally be furnished of sufficient length to extend at least 6 inches above the top of the battered masonry into the concrete coping, and special pains shall be taken to tamp the concrete thoroughly around the I-beams, and to finish the coping above and around the ends of the iron work.

Where anchor bolts for bridge-seat castings are required they shall be set in place and held firmly as to position and elevation, by templets, securely fastened to the mold and framing. Such I-beams and anchor bolts shall be embedded in the concrete work without additional expense beyond the price to be paid per yard for the several classes of concrete in which such iron is placed, the volume of iron being estimated as concrete.

After the work is finished and thoroughly set all molds shall be removed by the contractor. They shall generally be allowed to stand not less than 48 hours after the last concrete work shall have been done. In cold weather molds shall be allowed to stand a longer period before being removed, depending upon the degree of cold. No molds shall be removed in freezing weather, nor until after the concrete shall have had at least 48 hours, with the thermometer at or above 40 degrees F., in which to set.

Placing Concrete.—Concrete shall generally be placed in the work in layers not exceeding 6 inches in thickness, and, in general, one layer shall be entirely completed before another one is commenced. If delivered by wheelbarrows it shall be dumped as closely as possible where required, so as to avoid as much as possible the handling or turning over of the same by means of shovels within the excavation or mold. Where it is not practicable entirely to complete one layer before commencing a second one, a plank 6 inches wide or more shall be securely fastened into the excavation or mold, against which the end of the layer of concrete shall be rammed, thus providing for a vertical joint in this layer of concrete, and if a second layer has to be stopped short of the full length of the work, a second cross plank, placed at least 1 foot back from the end of the first layer, shall be secured to the excavation or to the mold, against which to ram the second layer of concrete. Layers of concrete masonry must not be tapered off in wedge-shaped slopes, but must be built with square ends in the method above described, and the surface of each projection shall be finished hard and smooth, and flushed full of mortar, no porosities or loose stone being left thereon.

Layers must not be made of greater thickness than 6 inches, unless specially permitted, and each layer must be thoroughly rammed, and the concrete must be of such consistency that heavy ramming will produce a slight quaking action. In other words, the concrete must be so thoroughly compacted that there will be no pores or open spaces between the stone of which it consists, which are not thoroughly filled with mortar.

The inspector shall insist upon the thorough compacting and ramming of all concrete, and shall see that a sufficient number of men, furnished with suitable rammers, are assigned to this work. Enough men shall be employed ramming so that each batch may be spread and rammed before another batch is dumped within the mold. The ramming must be completed as the work progresses.

Foundation concrete, if put into excavations which are not protected by molds, need not have any special attention given to the finish of the concrete against the earth around it. Where it is necessary to use molds in the construction of foundation work the finer material of the concrete shall be worked to the outer portion of the mass against the molds, so as to insure the filling with mortar of all pores or open spaces between the concrete stone. As before described, the top surface of all foundation concrete shall be finished so that no loose stone or open and porous places are left upon the same, especially in the portions of the foundation which project outside the upper portion of the work. If necessary, the inspector shall have the contractor make batches of mortar, consisting of 1 part of cement to 3 parts of sand, the same being thoroughly mixed, and shall cover the whole surface of the foundation concrete with enough of this mortar to flush full all such open, porous places.

A facing of mortar, consisting of 1 part of cement (by measure) to 2 parts of sand, shall be put in next to the molds, for all Portland cement concrete work for piers, abutments, arches, wing walls, parapet walls, and any other places where directed by the engineer in charge, to form a finish for all such parts of the above classes of work as are to be exposed to the weather, or which are liable to become exposed. A similar facing shall be used for the top surface of all concrete masonry not finished in the style of sidewalk work.

It is not intended to use such a facing on the backs of abutments or wing walls, against which earth filling is to be placed, and where the same must necessarily be maintained, but the same shall be used for the faces and for the upper 12 inches on the backs of all wing walls, for the backs of parapet

walls, for the intrados of all arch work, and as a plastering on the outside of the same, and in all such places where the washing away of earth may expose concerte work to the action of the weather. It is not intended to use such facing for any copings, bridge-seats, parapets, etc., which are to be of granitoid construction. The exact thickness of $1\frac{1}{2}$ inches for this facing shall be secured in the following manner: A piece of sheet iron 6 inches in width (the height of one course of concrete) and of any convenient length, say from 6 feet upwards, having small angle irons, the projecting leg of which shall be $1\frac{1}{2}$ inches in width, riveted to its face at intervals of about 2 feet and provided with handles standing above the upper edge at or near each end, shall be furnished by the contractor for use at each piece of work where necessary. This piece of iron plate, if placed with the projecting angles against the face of the mold, will leave a space of $1\frac{1}{2}$ inches between it and the mold. This space shall be filled with the mortar required for the facing, which mortar shall be mixed in small batches from time to time as needed for the work. When the space between the iron plate and the mold is filled and tamped with a shovel or other tool to insure complete filling of the whole space between the iron plate and the face of the mold, and when the layer of ordinary concrete is backed up against this iron plate, it is to be withdrawn by means of the handles and the whole mass of concrete rammed in one uniform layer. The inspector shall see that the space of $1\frac{1}{2}$ inches is entirely filled with the mortar, which should be of such consistency that it will flow somewhat freely. At the same time this mortar must not be made so thin that the crushed stone may be forced through it in the process of ramming. By using the mold in the manner above described the face of each layer may be made of exactly the right amount of mortar, and the proper thickness of the layer may be accurately determined. The intention is that the facing and the backing shall be rammed and set together. In no case is one to be put in in advance of the other, or so that either may be set before the other. In no case shall the inspector or engineer in charge permit any work to be finished by plastering mortar on concrete which has set, but should it become necessary at any time to refinish a surface which has set, it shall be picked off so that at least 3 inches of mortar can be added, and the surface of the old concrete shall be roughened and thoroughly wet before new material is added, such new material being mortar as specified for facing.

Layers of concrete shall be kept truly horizontal, and if, for any reason, it is necessary to stop work for an indefinite

period, it shall be the duty of the inspector and of the contractor to see that the top surface of the concrete is properly finished, so that nothing but a horizontal line shall show on the face of the concrete, as the joint between portions of the work constructed before and after such period of delay. If, for any reason, it is impossible to complete an entire layer, the end of the layer shall be made square and true by the use of a temporary plank partition. No irregular, wavy or sloping lines shall be permitted to show on the face of the concrete work as the result of constructing different portions of the work at different periods, and none but horizontal or vertical lines shall be permitted in such cases.

Where concrete is to be put into a foundation below water level, all water shall as far as possible be removed from the excavation. If it is impossible by means of the ordinary pumping facilities to control the flow of water, the excavation may be taken out in sections, and the concrete may be placed in the foundation, section by section. Special care should be taken to ram thoroughly the bottom layer of concrete, and to remove all mud and clay from the vertical face of each section of concrete, as additional sections are excavated and prepared for addition of concrete work. Where the foundation is soft, as, for example, where piles are used, either fine or coarse broken stone may be spread over the bottom of the excavation and thoroughly rammed into the earth before putting in any concrete. In no case shall a dry mixture of sand, cement and crushed stone be put into a foundation without thorough mixing. Where strata of gravel and sand permit the entrance of water into the foundation with such freedom that small sections of the same can not be excavated and pumped out for concreting, a grout of pure cement or of a mixture of cement and 1 or 2 parts of sand may be injected through a pipe into the loose gravel and sand in the bottom of the foundation; this work being done while the excavation is filled with water. The pipe through which this grout is passed should be pushed a few inches below the surface of the gravel, and a bucketful or more of grout should be poured down through the pipe, the pipe being then moved 1 or 2 feet and the operation repeated, distributing the grout over the whole area of the bottom to be thus cemented and the work then should be allowed to stand for 24 to 36 hours. It will generally be found that the sand and gravel will be converted into a water-tight concrete, permitting the pumping out of the excavation.

Where it is impossible to complete parapet walls, copings, etc., on account of stringers or other wood or iron work nec-

essary to maintain structures over which tracks are in use, all work shall be finished to horizontal and vertical lines, and with surfaces filled with mortar, so that when possible to complete the concrete work the joint between the new and the old work shall show nothing but straight, level and vertical lines.

Expansion Joints.—Where masonry structures are more than 100 feet in length, such provision for expansion joints shall be made as may be specified by the engineer of bridges or his assistants. Generally in the construction of large arches, or of smaller, long concrete arches, the work shall be subdivided into sections of approximately 25 feet in length, each section being separated from the adjacent one by a vertical joint extending entirely through the bench walls, arch rings, etc.; but the foundation work shall be stepped as previously explained, and made in one continuous monolithic mass. Temporary vertical partitions shall be put into the molds, against which the concrete shall be thoroughly rammed, where arch culverts are subdivided into short lengths as above specified, these partitions being removed as each section is completed, and the next adjacent section being rammed against the concrete already constructed and set. The joints thus made shall not be flushed with mortar, nor shall any attempt be made to make the fresh concrete adhere to the older work, but a small beveled strip of wood shall be set in the angle next to the temporary partition so as to make a "V" groove, defining the joint and leaving a depth of, say, 3/8-inch on the finished face of the work, it being the intention that any contraction shall open or that settlement shall effect a sliding action at such vertical joints, rather than to break up the concrete in the separate sections.

Pointing.—After the molds are removed, if there should be found any small pits or openings on the exposed faces of the concrete (or if bolts are used for securing the molds, the ends of which are removed, leaving small holes), all such holes, pits or porous places shall be neatly stopped with pointing mortar, made of equal parts of cement and sand and mixed in small quantities to be used before the same shall set. Although it has not been specified to use a facing of mortar for such masonry as is to be permanently buried or covered by earthwork, such masonry shall not be constructed and left with pores and honey-combed surfaces. All such pores and openings shall be stopped with a pointing mortar, composed of 1 part of cement and 2 parts of sand, the same to be neatly filled into all openings and smoothly finished, in advance of any filling against such work.

Name Plate and Date.—A name plate and date shall be furnished by the contractor and put upon one piece of masonry at each bridge or job constructed by him, such plate to be of brass or copper or other durable metal, furnished with bolts or projections on the back to be buried in the concrete and to secure it firmly to the same, and having on it the contractor's name and the date of the year in which the concrete work is constructed. These plates should be placed upon the parapet walls of abutments, concrete arches and pipe culverts, and upon the ends of the bridge seats of piers, where they can be plainly seen and easily read. These should be set as the concrete work is finished and should be level with the surface of the same.

Extra Work.—It is the intention of the foregoing specifications that work of all kinds shall be done by unit prices. It shall be paid for at rates per unit of measure of the several kinds of work required. Wherever, in the judgment of the engineer in charge, such prices are unfair to the contractor, the conditions shall be fully explained to the engineer of bridges, whose permission shall be obtained in writing for all extra work to be done. Generally such work shall be done at the actual cost, and the contractor shall be allowed 10 per cent. in addition, to cover the superintendence, the use of tools, etc. No other rate will be allowed, unless specially provided when the work is ordered.

A daily report of forces employed and material used in all extra work shall be made by the foreman on the work to the assistant engineer or inspector in charge of the work, who shall check the same from day to day and settle all disputed questions as to labor and material used. A return of all such extra work shall be made by the contractor (or by his foreman) at the end of each month, which shall be given to the engineer or inspector on the work for certification, and shall be sent to the engineer of bridges, with the estimate of work done at contract prices, so that the monthly estimate may cover all work done during the month. In general, all bills for extra work claimed to have been done by the contractors shall be rendered monthly and shall be certified to by the engineer or inspector in charge of the work.

EXTRACTS FROM THE RULES AND INSTRUCTIONS FOR MASONS ON "COMPANY" WORK OF NEW YORK CENTRAL AND HUDSON RIVER RAILROAD.

Concrete Mixing.—Mix the cement and sand as follows: Spread about one-half of the sand to be used in a batch of mortar evenly over the bed of the mortar box, then spread the cement evenly over the top of the sand, and finally spread

the remainder of the sand on top. The sand and cement should then be thoroughly mixed by turning and returning at least six times with a shovel. The mixture is then drawn to one end of the box and water poured in at the other end. Then draw the mixture down to the water with a hoe, small quantities at a time, and mix vigorously until there is a good stiff mortar. Enough water should be used so that the mortar will work well under the trowel. Then level off the mixture and spread over it the required amount of broken stone or gravel, which should be first moistened; then thoroughly mix the whole mass by turning and returning it with shovels in rows, at all times preserving the same thickness of the mass, until the mortar thoroughly fills all the interstices.

A thorough mixture of the ingredients is the first condition of a good concrete.

A mortar box with detachable sides will be found economical and convenient for concrete mixing.

Concrete Laying.—After the concrete is mixed it should be quickly laid in sections, in layers not exceeding 8 inches in thickness; and shall be thoroughly rammed with 2-man rammers, weighing not less than 30 pounds each, until the water flushes to the surface. It shall be allowed at least twelve hours to set before any work is laid on it. Concrete mixed for over one hour will not be allowed in the work.

Forms of timber shall be used wherever necessary to maintain the dimensions of the concrete shown on the plans.

Facing Concrete.—Concrete for facing old masonry shall consist of 1 part best quality Portland cement, 2 parts clean, coarse, sharp sand, and 4 parts of $\frac{3}{4}$-inch broken stone, with outer facing consisting of a mortar of the proportions of one part Dyckerhoff, Germania, or other approved imported Portland cement, to 2 parts clean, coarse, sharp sand of an average thickness of 1 inch deposited simultaneously with the backing; to be securely fastened to the old masonry with anchors and twisted rods as shown on the standard plan. Use molds as specified below. (American cements are now used.)

Molds.—The concrete shall be deposited in molds made from dressed matched siding firmly held in place by exterior braces, posts, etc.; or by bolts or ties so made as to be removed from the work and leave no iron within 1 inch of the face of the finished work. The siding shall be set truly horizontal, with butt-joints truly vertical and with the faces against which the concrete is to be placed, dressed, and set to true planes, and covered with soft soap or other approved material to prevent "sticking." After the molds are re-

moved, any open or porous places shall be neatly stopped with pointing mortar; and if so directed by the engineer, the exposed faces of the work shall be washed with neat Portland cement to give a uniform, smooth finish to the exposed surfaces.

Temperature Changes.—In large structures, provision for expansion and contraction shall be made by tarred paper, vertical joints not less than 50 feet apart extending through the mass. Wet down all outside surfaces each day until the expiration of two weeks after the entire work is completed.

SPECIFICATIONS FOR CONCRETE OF THE CHICAGO AND ALTON RAILWAY COMPANY.

Concrete will, in general, consist of a matrix of cement mortar and an aggregate of broken stone or gravel, or a combination of broken stone and gravel.

Materials.—The cement used shall conform to the C. & A. Ry. Co. specifications.

The sand shall be practically free from clay, loam, sticks, leaves and other foreign substances, but may contain occasionally pieces of small gravel. The sand shall be so coarse that not more than 40 per cent. of it will pass through a No. 50 sieve, 50 meshes per linear inch.

The broken stone shall be of sound lime stone, which shall be composed of angular fragments, no piece of which shall exceed two inches in greatest dimension. It shall be clean and free from dust, dirt or other foreign matter, but may consist in part of fine screenings and medium-sized pieces, the intention being to take all of the product of the crusher except the fine dust.

The gravel shall be clean and free from dust, dirt and other foreign substances, and shall contain no stones over two inches in diameter. When gravel containing considerable quantities of sand is used, several trials must be made to determine the proportion of sand it contains that will pass through a No. 4 screen, and a corresponding deduction shall be made from the sand used in making the mortar, so that the final proportions of the cement and sand in the complete mixture shall be as specified for mortar.

Only the gravel remaining after screening out the sand shall be treated as aggregate during the experimenting for voids referred to later.

Proportions.—In general, the following proportions will be used:

In footing courses and foundations below frost line the matrix or mortar shall be 1 part packed natural cement to 1½ parts loose sand.

In the body of the structure the matrix shall be 1 part packed Portland cement to 3 parts loose sand.

When the cement is packed in barrels the barrel shall be the basis of measure for the sand and also for the aggregate. But when the cement is packed in sacks, 3½ cubic feet shall be considered a barrel of sand or aggregate.

When the aggregate is composed of both broken stone and gravel they shall be mixed in such proportions (to be determined by experiment) as will give the ieast per cent. of voids when mixed.

In general, the amount of mortar mixed with the aggregate shall be at least 10 per cent. more than the voids in the loose aggregate, which the engineer shall determine by experiment.

In experimenting for voids, where possible, the method of weights shall be used, assuming the weight of dry gravel and broken stone to be 165 pounds per solid cubic foot, and excluding from the aggregate the sand which occurs in the gravel.

In copings and the top foot in depth of parapet walls the concrete shall contain about ⅛ less aggregate for a given amount of mortar than the standard mixture for the body of the structure.

The amount of mortar made by given amounts of cement and sand shall also be determined by experiment, but in the absence of such experiments for special cases the following may be used as an approximation, the units of cement being a barrel of 380 lbs. net for Portland, and 265 lbs. net for natural cement.

	PROPORTIONS.	CEMENT.	SAND.	RESULTING MORTAR.
Portland Cement	1 to 1	1 bbl.	3.5 cu. ft.	6 0 cu. ft.
	1 to 2	1 bbl.	7.0 cu. ft.	8.0 cu. ft.
	1 to 3	1 bbl	10.5 cu. ft.	10.7 cu. ft.
Natural Cement.....	1 to 1	1 bbl.	3.50 cu. ft.	5.7 cu. ft.
	1 to 1.5	1 bbl.	5.25 cu. ft.	6.9 cu. ft.
	1 to 2	1 bbl.	7.00 cu. ft.	7.8 cu. ft.

When necessary to use concrete without making the above experiment for voids in the aggregate, the following proportions shall be used unless others are specified:

Footings—1 bbl. natural cement to 5¼ cubic feet loose sand to 17 cubic feet loose aggregate.

In the body of the structure, 1 bbl. Portland cement to 10.5 cubic feet loose sand to 25 feet loose aggregate.

For copings and the upper foot of parapet walls, 1 bbl.

Portland cement to 10.5 cubic feet loose sand to 22 cubic feet loose aggregate.

In all cases the proportions shall be reduced to such a basis that they can be stated as follows in terms of the actual materials as delivered on the ground for use:

One bbl. cement to..........cubic feet sand to.......... cubic feet gravel to..........cubic feet broken stone.

The proportions so stated, together with descriptions of all experiments leading thereto, shall be submitted to the chief engineer for approval, and after approval shall be followed in measuring the materials until there is reason to change them through change in condition of materials received. The necessity for such change shall be determined by the engineer and approved by the chief engineer.

Mixing.—Great care must be used to get even mixing, and preference will be given to approved mechanical mixers.

When the mixing is done by hand, the sand shall be spread first and the cement on top of it, and they shall be mixed dry by turning with shovels or hoes, until the mixture is of uniform shade and free from lumps of sand or cement. Water shall then be applied by sprinkling the mixture while turning it. The mixing shall then continue until the mortar becomes of a uniform dampness throughout. It shall then be spread out, and the aggregate having been thoroughly wet down, shall be spread upon the mortar and the two turned together from three to five times, or until the mixture appears to be perfectly uniform throughout.

The aggregate shall be frequently wet down, especially in warm weather, so that the pieces of broken stone and gravel, when mixed with the mortar, will be saturated and will not absorb water needed for the compacting and setting.

Sufficient water shall be used in the mixing to insure the closing of all voids by a moderate amount of ramming. This can only be insured by slight quaking during the ramming.

Placing.—The concrete shall be thoroughly rammed in layers of from six to nine inches, as directed by the engineer. The tamping tools shall be at least six inches square at the bottom, and the bottoms shall be kept clear of hardened mortar so as to pack the concrete with flat surfaces. The layers, or courses, must be horizontal and should be placed continuously over the whole area within the forms. Where this is impracticable, and one or two benches are necessary, care must be taken to prevent the appearance on the face of the structure of any irregular lines due to the concrete in these benches setting before they are covered with fresh concrete.

When permitted to set before being covered, footing courses must be left rough on top to give a good hold for the

superimposed concrete. This shall, at the discretion of the engineer, be accomplished by embedding pieces of plank in the top of the footing course, to be removed after the concrete has set, leaving depressions. Beveling the edges of these planks will facilitate their removal.

This method, or other methods approved by the engineer, shall be used whenever it is necessary to leave work unfinished over night or for a longer time. When work is resumed the surface of the concrete already set shall be thoroughly wet down and washed over with a thin mortar of 1 part cement to 1 part sand just before depositing the next layer of concrete. Work shall never be stopped within two feet of the top of the coping, unless absolutely necessary.

All mortar shall be mixed fresh for the work in hand, and no mortar or concrete shall be used which has begun to set before tamping in its final position.

Exposed Surfaces.—All faces to be exposed or liable to become exposed in the finished structure shall be given a good smooth surface by working the mortar and finer concrete next to the form with a shovel or spade. No plastering on any exposed surface after forms are removed, will be permitted, and pointing of holes in the face must be reduced to a minimum by the above method.

Top surfaces, both horizontal and inclined, shall be finished by covering with one-half inch of mortar composed of 1 part cement to 2 parts sand, and placed before the concrete under it has begun to set. It shall be rubbed smooth.

Vertical Joints.—In long, continuous concrete structures liable to considerable changes of temperature, such as retaining walls, provision shall be made for expansion and contraction. This shall be accomplished by the use of temporary vertical partitions extending from the footing course to the top and dividing the structure into sections approximately 25 feet long. Each section shall be finished to the top before the adjoining section is started, and no attempt shall be made to make the sections adhere to each other, so that when cold contracts the structure it will open up slightly in these vertical joints, and not in an irregular crack.

A plank shall be spiked vertically to the face of the partition against which the concrete is to be rammed, so that a depression will be formed in the end of the section, giving the effect of tongue and groove joints in the finished wall.

Protection of Surface.—When work is stopped, either before or after completion, the surface of the concrete recently placed shall be wet down and covered in some manner accept-

able to the engineer to protect it from the weather and from rapid drying out through evaporation.

Footings.—The laying of concrete below water line, or in wet ground, shall be protected by cofferdam or sheeting in manner acceptable to the engineer, and if in his judgment it is demanded, Portland cement concrete shall be substituted for natural cement concrete.

Cold Weather.—When it is necessary to make concrete in freezing weather only Portland cement concrete will be used, and the materials shall be heated by steam or otherwise, and hot water used in the mixing.

In general, less water shall be used for mixing in cold than in warm weather, and in no case shall a surplus of water be allowed to accumulate and freeze on top of a layer of concrete and then be covered up with more concrete before thawing out.

Forms.—Forms shall be constructed so that their inner surfaces will conform strictly to the dimensions called for by the plans of the structure. The plank used for exposed faces shall be dressed on both edges, and at least on one face to a uniform thickness, and such care shall be used in constructing the form that the finished concrete structure will present a smooth, unbroken surface.

The facing plank shall be of sufficient thickness and the uprights sufficiently strong and frequent to prevent any springing of the form when the concrete is rammed in place.

Where rods are used to hold the front and back of the form together they may left in the concrete if a sleeve nut is used at least three inches back from the face, and the outer end of the rod removed, and the hole rammed full of mortar 1 part cement to 3 parts sand.

Provision shall be made for rounding off all angles between exposed surfaces by using in the form small quarter-rounds and coves to fill these angles.

The walls of the wooden forms shall be kept wet during the progress of the concrete work.

Forms shall not be removed sooner than directed by the engineer.

Interpretation.—The requirements of these specifications in any particular are subject to modification by the chief engineer, who will decide all questions as to their interpretation.

NEW YORK RAPID TRANSIT RAILWAY.

The proportions of mortar by volume are for the various classes of work as follows:

Brick masonry: 1 portion of Portland cement and 2 portions of sand.

Column footing stones: 1 portion Portland cement and 2 portions sand.

Stone masonry: 1 portion Portland cement and 2½ portions of sand.

Rubble masonry: 1 portion natural cement and 2 portions sand.

Pointing: 1 portion Portland cement and 1 portion sand.

The requirements for concrete are as follows:

The concrete shall be composed of sound, clean, screened all dirt and dust, and mixed together with the proportion of mortar specified below. The broken stone or gravel used for concrete for the finishing floor of the railway, must not exceed gravel or sound broken stone, or a mixture of both, free from 1 inch at their largest diameter. For all other concrete the maximum diameter for broken stone or gravel, unless specifically permitted by the engineer, must not exceed in any direction 2 ins., with a minimum diameter of ¼-in. In all concrete where the thickness is 30 ins. or more, the contractor may imbed in the same broken pieces of sound stone whose greatest diameter does not exceed 12 ins. and whose least diameter or thickness is not less than ¾ the greatest diameter. These stones shall be set by hand in the concrete as the layers are being rammed, and so placed that each stone is completely and perfectly bedded. No two stones are to be within six ins. of each other and no stones within 4 ins. of an exposed face.

The proportions of mortar and stone used in making concrete shall be as follows: Concrete in arches of roof and side walls, where the thickness does not exceed 18 ins., 1 portion Portland cement, 2 portions sand, 4 portions stone. Concrete in side walls or tunnel arches, where backing is rock in place, 1 portion Portland cement, 2½ portions sand and 5 portions stone. Concrete in foundations in wet ground, where thickness, exclusive of finishing floor concrete, does not exceed 24 ins., 1 portion Portland cement, 2 portions sand, 4 portions stone. Concrete in foundations in wet ground where thickness, exclusive of finishing floor concrete, exceeds 24 ins., 1 portion Portland cement, 2½ portions sand, 5 portions stone. Concrete in foundations in dry ground, 1 portion Portland cement, 2½ portions sand, 5 portions stone. Concrete in foundations, where on rock, if not exceeding 12 ins. in thickness, 1 portion Portland cement, 2½ portions sand, 5 portions broken stone; if exceeding 12 ins., 1 portion Portland cement, 3 portions sand, 6 portions broken stone.

(Note.—If the rock is dry, natural cement may be substi-

tuted for Portland cement in above, but increasing the quantity of cement used 30 per cent..) Concrete in mass, such as retaining walls, or backing of masonry retaining walls, in dry ground, 1 portion natural cement, 2½ portions sand, 5 portions stone. If such retaining walls or backing are in wet ground, or subject to extraordinary strain, then Portland cement shall be substituted for natural..

The broken stone or gravel shall be spread on a platform sprinkled with water, and then thoroughly mixed with the mortar in the proportions as specified above. Machinery for the mixing of concrete may be used if approved by the engineer. The concrete shall be laid immediately after mixing and be thoroughly compacted throughout the mass by ramming. The amount of water used in making concrete shall be approved by the engineer. The concrete shall be allowed to set for 12 hours, or more, if so directed, before any work shall be laid upon it; and no walking over or working upon it shall be allowed while it is setting. Before laying concrete on rock surfaces the latter shall be swept clean of all debris and dirt. Whenever it becomes necessary to lay fresh concrete next to or on top of concrete in which the mortar has already set, the surface of the old concrete shall be well washed, and a thin layer of clear cement shall then be spread over it immediately previous to the laying of the fresh concrete. Suitable molds shall be provided by the contractor to support the concrete while being rammed in the walls or roofs. These molds shall be immediately replaced by new ones as soon as they commence to lose their proper shape. Before being used they shall be carefully cleaned of cement and dirt and shall present to the concrete on the surface afterwards exposed to sight a perfectly smooth surface, to be obtained by covering each portion of the molds with sheet metal, or by carefully planing the wood and coating the face of the same with black oil. In no case on an exposed surface of the concrete must the joints of any component pieces of the mold, nor the grain of the wood, be visible. The molds shall be set true to line, firmly secured, and be so tight as not to allow water in the mortar to escape. They shall remain in place until the concrete is thoroughly set, and in event of pressure coming at once on the concrete, such additional time as the engineer may direct. On removing the molds, if any voids or irregular connections with the steel framework are discovered, such defective work shall be cut out and filled with a rich concrete or mortar, in such proportions and in such manner as the engineer may direct.

MAINTENANCE OF WAY ASSOCIATION.

The American Railway Engineering and Maintenance of Way Association has adopted specifications for concrete from which the following points are abstracted:

(1) Forms shall be well built, substantial and unyielding, properly braced or tied together, by means of wire or rods, and shall conform to lines given.

(2) For all important work the lumber used for face work shall be dressed on one side and both edges to a uniform thickness and width, shall be sound and free from loose knots, and secured to the studding or uprights in horizontal lines.

(3) For backings and other rough work undressed lumber may be used.

(4) Where corners of the masonry and other projections liable to injury occur, suitable moldings shall be placed in the angles of the forms to round or bevel them off.

(5) Lumber once used in forms shall be cleaned before being used again.

(6) The forms must not be removed within 36 hours after all the concrete in that section has been placed. In freezing weather they must remain until the concrete has a sufficient time to become thoroughly set.

(7) In dry but not freezing weather, the forms shall be drenched with water before the concrete is placed against them.

The specifications require that the concrete shall be of such consistency that when dumped in place it will not require much tamping. It shall be spaded down and tamped sufficiently to level off, and the water should rise freely to the surface.

The surface finish is described thus:

After the forms are removed, which should be as soon as possible after the concrete is sufficiently set, any small cavities or openings in the face may be neatly filled with mortar, if necessary in the opinion of the engineer. Any ridges due to cracks or joints in the lumber shall be rubbed down with a chisel or wooden float. The entire face may then be washed with a thin grout of the consistency of whitewash, mixed in the same proportion as the mortar of the concrete. The wash should be appplied with a brush. The earlier the above operations are performed the better will be the result.

In the discussions it appeared that expansion joints are needed at lengths of about 30 feet, and that with proper care in the selection of lumber and in constructing the forms it may

not be necessary to go to further expense in finishing the faces of concrete work after removing the forms.

Freezing Weather.—Ordinarily concrete to be left above the surface of the ground will not be constructed in freezing weather. Portland cement concrete, however, may be built under these conditions by special instructions. In this case the sand, water and broken stone shall be heated, and in severe cold salt shall be added in the proportion of about 2 pounds per cubic yard.

Reinforced Concrete.—Where concrete is deposited in connection with metal reinforcing the greatest care must be taken to insure the coating of the metal with cement, and the thorough compacting of the concrete around the metal. Wherever it is practicable the metal should be placed in position first. This can usually be done in the case where the metal occurs in the bottom of the forms by supporting the same on transverse wires, or otherwise, when the bottoms of the forms can be flushed with cement mortar, so as to get the mortar under the metal at the same time, and the concrete deposited immediately afterward. The mortar for flushing the bars should be composed of one part cement and two parts sand. The metal used in concrete shall be free from dirt, oil or grease. All mill scale should be removed by hammering the metal, or preferably by pickling the same in a weak solution of muriatic acid. No salt shall be used in reinforced concrete.

In the discussions attending the adoption of the foregoing clauses, it appeared that a considerable amount of reinforced concrete work has been done recently on railroads centering ing in Chicago during freezing weather. It was stated that where the materials are properly heated, as specified above, the mass of concrete does not fall to a freezing temperature for about 24 hours later even when the temperature is below zero during the period. It was suggested by a chemist present at the meeting that where the metal is pickled in acid it should be thoroughly washed afterward so as to remove the acid before depositing the concrete.

HEAVY MONOLITHIC CONCRETE MASONRY.

From a description given in a paper by Jas. C. Long before the Western Society of Engineers, the following specifications and instructions regarding the construction of canal lock masonry on the Illinois and Mississippi canal are taken:

Proportions and mixing of concrete:

Proportions and ingredients are measured by volume, and the numbers of cubic feet given below represent the quantities to be used for each charge of concrete put into the mixer.

Portland cement concrete shall in general consist of:

Portland cement	1 part	5 cu. ft.	5 sacks.
Gravel	4 parts	20 cu. ft.	
Broken stone	4 parts	20 cu. ft.	

For the wall supporting the upper gate and in the vicinity of the quoins the concrete shall consist of:

Portland cement	6 cu. ft.	6 sacks.
Gravel	20 cu. ft.	
Broken stone	20 cu. ft.	

Natural cement concrete shall consist of:

Natural cement	2 parts	8 cu. ft.	4 sacks.
Gravel	5 parts	20 cu. ft.	
Broken stone	5 parts	20 cu. ft.	

Facing material shall consist of, by volume:

1 part Portland cement.

3 parts Torpedo sand passing No. 5 sieve.

The piles of gravel and broken stone shall be kept thoroughly sprinkled with water to clean surface of dust and to prevent absorption by the dry stone of the water used in mixing the concrete.

When delivered in bags, each bag of cement shall be emptied directly into the charging box, as the division of a barrel of cement into several bags diminishes the chances of injurious effect of a defective barrel, and hence the usual requirements of drawing charges from a mixture of five or more barrels may be dispensed with. When delivered in barrels this latter requirement will be observed.

All bags and sacks shall be carefully preserved for return to the dealer furnishing cement, in order to secure to the United States the rebate thereon, to be deducted from subsequent bills for cement.

The proper measures of ingredients shall be emptied into the charging box in the following order: 1st, gravel, 2d, cement; 3d, broken stone; 4th, water.

Enough water shall be added to make the concrete cohere after a thorough mixing. A greater degree of plasticity than that possessed by damp sand is required. The object is to have the consistency such that a thorough ramming will bring water to the surface. The mass of concrete should not quake on ramming; incipient quaking marks the limit, and any excess of water in one charge may be corrected by making the next charge a little dryer. The proper amount of water can be determined only by experience, and must be varied from time to time to

suit the conditions of the weather and the ingredients. It is very important that Portland cement shall have sufficient water for its complete hydration. Natural cement requires less water for hydration than Portland.

The contents of the charging box shall be dumped immediately into the cubical mixer, which shall be revolved for not less than two minutes at a rate not exceeding nine revolutions per minute. The product is improved by long mixing, and all the time less than period required for initial set available between deliveries required at the forms should be utilized for extra turns to the mixer. The facing material shall be mixed by hand, and a very small gang will be able to keep the forms supplied. For a facing of uniform thickness of 2 inches, about 70 cubic yards only will be required for a lock, or about 3½ cubic yards to each section. A close watch must be kept of the quantity used, and the above limit must not be exceeded.

Depositing and ramming concrete:

Each lock shall be built in sections, averaging about 20 feet in length, making 10 sections to each wall. The planes of division between sections shall be at right angles to the axis of the lock, and are indicated on drawing furnished from this office.

Each section shall be a monolithic mass of concrete built continuously from the bottom to completion without horizontal joints. The sections shall be filled with horizontal layers about 6 inches thick, each layer to be deposited before the "initial" set of the previously deposited layer and then be well rammed in place.

The vertical planes of division between sections shall be made by transverse bulkheads built in the forms, and at each bulkhead a dovetail or recess shall be made for the interlocking of adjacent sections, the dovetails reaching from foundation to one foot below the coping of the sections.

Alternate sections shall be built first, then the bulkheads shall be removed and the remaining sections filled with concrete.

Before beginning a section, its foundation shall be swept clean with wire brooms and covered with a wet layer one inch thick of 1 to 1 cement mortar to make a close joint between the wall and the foundation.

The walls of the wooden forms shall be kept well wet during the progress of the concrete work to prevent their absorption of water from the newly placed concrete.

The lowest step or thickest part of the lock walls shall consist of not less than two feet of Portland cement concrete next to the face of the wall and a backing of natural cement concrete. All other walls or parts of walls shall be of Portland cement concrete.

The exposed faces shall consist of Portland cement and torpedo sand, 1 to 3. The thickness of facings shall not exceed $1\frac{1}{2}$ inches nor be less than $\frac{3}{4}$ inch.

The facing and backing must go on simultaneously in the same horizontal layers. In order to gauge the thickness of the facing accurately, a light board or diaphragm of thin metal with convenient handles shall be set on edge parallel to and $1\frac{1}{2}$ inches from the front wall of the forms. The facing material shall be deposited in the space between this board and the form. The concrete of the backing shall then be deposited and spread against the back of the board, which may then be withdrawn and the whole mass thoroughly rammed so as to bond the facing and backing by destroying the surface of demarcation between them; but no stone must be forced nearer to the front wall of the form than $\frac{3}{4}$ inch. No attempt shall be made to secure a definite surface between the Portland and natural cement concrete in the lowest step of the lock walls, but they shall be thoroughly bonded, blended and interlocked one into the other by long lap or splice joints in every layer deposited.

The top 6 inches of wall should have no broken stone—1 part Portland cement, 4 parts gravel with large stones cast out. The top of coping for not more than 1 inch should be placed as soon as practicable upon this gravel concrete, mixed 2 parts cement and 3 parts torpedo sand, of consistency of mason's mortar, but quite wet, not stiff. It should be dumped and rapidly spread over the concrete and roughly finished. It should then be left to begin to stiffen and "shed its water"; but before its "initial set," and while still plastic, it should be finally finished smooth, well pressed and compacted into a firm, smooth coat and slightly crowned in the center.

As soon as the setting is sufficient to stand it, the coping should be well sprinkled with water, and covered from air and sun for several days, keeping it well wet until set hard.

The facing and coping shall show a smooth, dense surface without pits or irregularities. This is most likely to be secured by thorough and systematic ramming.

Concrete shall not be laid in water nor exposed to the action of water until thoroughly set. Concrete or mortar shall not be made when the temperature is lower than 35 degrees Fahrenheit in the shade, nor when rain is falling on it. All concrete work shall cease November 20, and not be resumed before April 1. Forms and molds must be left in position for not less than four days after concrete is deposited. Freshly deposited concrete shall be protected from the direct rays of the sun and from wind by boards or tarpaulins, and as soon as a section of wall is completed the exposed coping must be covered with a

thick layer of wet sand, and the whole mass of wall must be kept sprinkled until the concrete is thoroughly set.

Twenty-one locks were built as above. They are 170 feet long between gates, 35 feet wide in lock chamber, and have an average lift of $9\frac{1}{2}$ feet. They contain, exclusive of foundations, an average of 2,567 cubic yards of concrete masonry to each lock, which cost $6.78 per cubic yard.

The average time consumed in placing this concrete masonry was 10 days for each lock. The longest time was 13 days and the shortest time was 8 days. The average amount of concrete placed per day was 256.7 cubic yards, and the largest average per day on any one lock was 320 cubic yards.

A CONCRETE BLOCK DAM.

The following is an abstract of the concrete portion of the specifications for the dam of the Lynchburg, Va., water works, built of concrete blocks:

Portland cement concrete shall be composed of one part Portland cement, two and one-half parts sand and four and one-half parts ballast. Hydraulic cement concrete shall be composed of one part hydraulic cement, two parts sand and four parts ballast.

The concrete in the dam shall be built up in large blocks, each block being formed in place and completed at one operation. The blocks on the upstream face of the dam, the crest, and the downstream face shall be formed of Portland cement concrete. The blocks in the heart of the dam shall be formed of natural hydraulic cement concrete.

Each block of concrete shall be built between substantial timber forms securely braced in place. The surfaces of the forms against which the concrete is to be deposited shall be smooth, laid close together and spiked to the vertical posts or framework. The lumber need not be planed. The vertical grooves in the concrete blocks shall be formed by securing 2x10-inch planks against the interior surfaces of the forms. The horizontal tongues on the tops of the blocks shall be formed between properly prepared molds laid upon the surface of the wet concrete after bringing the same up to the proper level, and the concrete forming the tongue shall be deposited in place before the concrete underneath shall have set, and shall be thoroughly tamped and bonded thereto. All vertical and horizontal tongues and grooves shall be continuous throughout the length and depth of each block of concrete.

The blocks forming the upstream face of the dam shall be laid alternately as headers and stretchers, the depth of the courses being 5 feet. The stretchers shall be 2 feet 6 inches deep

on their beds and 6 feet long, and the headers 3 feet wide and 4 feet 6 inches long.

The blocks forming the heart of the dam shall be, in general dimensions, not larger than about 10 feet by 15 feet, but shall be of irregular rectangular shapes, with horizontal beds and vertical sides. The beds of the large blocks shall be stepped, in a manner to break joints with other contiguous blocks, so as to give a thorough bonding both horizontally and vertically. On the tops of the blocks in the interior of the dam the tongues shall be run approximately parallel to the upstream face of the dam, shall not be less than 6 inches high and shall vary in width from 12 inches to 24 inches, according to the way the blocks interlock. In horizontal planes the large blocks shall be offsetted in the general manner shown on the plans, but the actual form of each block will depend upon the shapes of those in the lower layers, the forms being arranged so that thorough bonding and breaking of joints will be secured.

The concrete shall be deposited in the blocks in the following manner: Over a portion of the prepared bottom a layer of concrete about 6 inches thick shall be spread, leveled off and thoroughly tamped; upon this shall be lowered a large stone, a proper mortar bed having been prepared to receive it. The stone shall be jolted and worked down to secure a perfect bed, and shall be raised and rebedded as often as necessary to secure a perfect bedding. Another large stone shall be similarly bedded, and the operation kept up until the entire area of the bottom of the block is covered with concrete. The selecting and placing of the large stones shall be so done that no stones will be nearer together, or nearer to the forms, than 6 inches at any place. The spaces between the stone and forms shall then be filled with concrete in layers about 9 inches thick, each layer being thoroughly and solidly tamped to secure perfect bonding with the stones and forms.

During the placing of the concrete around the stones the latter shall be kept wet by sprinkling with clean water, and all stones, before being placed in the blocks, shall have been roughly trimmed up to remove all feather edges, splinters and checked portions, and shall have been washed clean with clean water to remove all dirt, dust and loose particles. None but sound quarry stones, roughly rectangular in shape, free from checks, cracks, decomposed faces, sliver edges, and other undesirable qualities, shall be used.

The sizes of the stones will vary according to the yield of the quarry, but it is desirable to use stones as large as can be economically gotten out, transported and handled. Their sizes will depend somewhat upon the quality of their beds, as

the difficulty of forming a good bed joint increases with the sizes of the stones. The quality of the beds must be good for materials of this class, and present such even surfaces that, when lowering a stone into place, there can be no doubt that the mortar will fill all spaces.

The sizes of the concrete blocks shall be such that each block, including the tongues on the top therof, can be finished in one day. Each block, when finished, must have its top surfaces horizontal, comparatively even and smooth, absolutely dense and compact, with no voids showing between the stones of the concrete, and exhibiting a surplus of mortar all over the top. After each block is completed the forms shall be left in place until permission to remove them is given by the engineer. The top of each block shall be covered with boards, canvas, damp sand and other protective covering, and shall be kept dampened with water, if so directed by the engineer, until the concrete has thoroughly hardened and set and there is no longer danger of drying and cracking. The contractor shall so lay out and arrange his work that each block shall have had at least one week to set before another block is joined to it, or built upon it, to allow for the change in volume following the setting of the concrete.

Before starting a new block between those already constructed, the contractor shall remove all feather edges, and all portions of the work that may accidentally have been injured, sweep up all dust and debris and thoroughly drench, with clean water, the surfaces of the old concrete against which the new work is to join. He shall then paint over all vertical and horizontal joints in the surrounding blocks with a thick wash composed of equal parts of Portland cement and slaked lime, the lime, before using, having been slaked for at least fourteen days and having been run through a fine screen to remove lumps and particles of unburned stones. This wash shall be applied in a strip about 8 inches wide, 4 inches each side of and covering the joint, put on thickly with short handled brooms or brushes, and thoroughly filling all corners and angles.

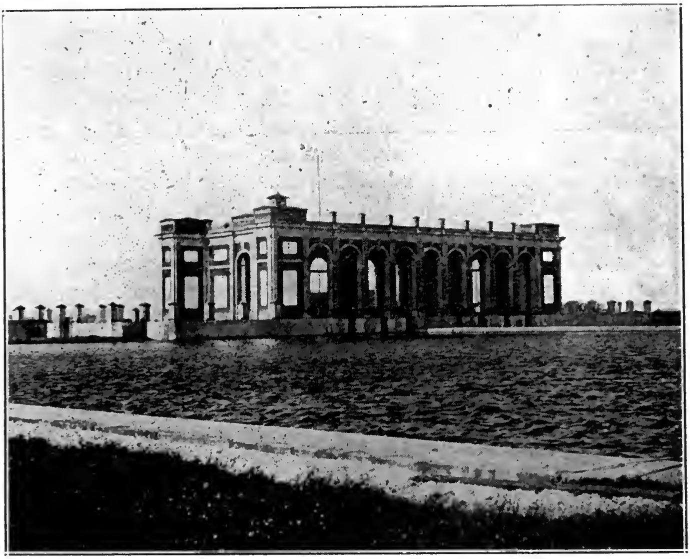
Wing walls either side of the spillway, the walls of the gate-chamber and the parapets of the main dam are to be reinforced with twisted square steel rods. The downstream edge of the crest of the spillway will be of cut stones doweled together with 1-inch steel pins 6 inches long and anchored to the concrete by means of ½-inch twisted square steel rods bent around the dowels into the form of a long U and extending 6 to 7 feet into the concrete. The treads of the spillway steps will be of sound granite blocks 18 to 27 inches deep and large enough to extend about 2 feet under the next step above. Exposed faces of these

blocks are to be rough pointed and the joints between them are not to exceed 1 inch.

The top of the main dam is to be 10 feet wide at an elevation 8 feet above the spillway crest, and at both downstream and upstream faces parapets will rise 2½ feet above the ordinary full-reservoir level. Each parapet is to be reinforced near its top by a 1-inch steel rod extending its entire length. The surfaces of the parapets and of the top of the dam between them, the top of the spillway and the tops of the steps of the wing walls, will be finished with a 1-inch coat of 1 to 1 Portland cement mortar, applied to the concrete before the latter has set and troweled down hard and smooth. The coating on the vertical faces, however, is to be deposited in the forms with the concrete.

CONQRETE RESERVOIR LINING.

The following from a paper before the New England Water Works Association by C. M. Saville, gives the method and the



CONCRETE LINED RESERVOIR, HAVANA WATER WORKS.

important specifications for lining the Forbes Hill Reservoir at Quincy, Mass.

The bottom and slopes of the reservoir were lined throughout with two layers of concrete masonry, separated by a layer of Portland cement plaster, 1½ inches in thickness.

Concrete masonry (Class C), composed of 1 part of American natural hydraulic cement, 2 parts of sand and 5 parts of stone, was used for the under layer of concrete on the bottom of the reservoir.

Concrete masonry (Class D), composed of 1 part of Portland cement, 2½ parts of sand and 6½ parts of stone, was used for the under layer of concrete on the slopes of the reservoir.

Concrete masonry (Class E), composed of 1 part of Portland cement, 2½ parts of sand and 4 parts of stone, was used for the upper layer of concrete on the bottom and slopes of the reservoir.

It was specified that the cement should be properly tested, that the sand should be of approved quality, and that either clean gravel, stone or crushed rock should be used in the concrete.

None of the stones were to be larger than 2½ ins. in their greatest diameter and those used in the upper layer of the reservoir lining were limited to 1½ ins.

The layer of plaster between the concrete layers was put down in strips about 4 ft. wide and finished similar to the surface of a granolithic walk. This layer was mostly composed of 1 part Portland cement to 2 parts sand, with a finishing surface composed of 4 parts cement to 1 part sand. Long strips of coarse burlap soaked in water were used to keep this layer wet and cool. In spite of these precautions some cracks appeared which were grouted before being covered with concrete. Three gangs, each of a plasterer and helper, were employed on this work, each gang laying about 700 sq. ft. per day.

The upper layer of the concrete lining was formed in blocks about 10 ft. sq. on the bottom of the reservoir and 8x10 on the slopes. These blocks alternated in both directions, one-half being first laid and allowed to set. The surface of these blocks on the slopes was left about 1 in. low and finished with a layer composed of the same proportions as the balance of the block, but stone dust, and stone less than ⅜-in. was substituted for the 1½-in. stone. This layer was applied before the under concrete set and was finished to a firm, smooth surface, true to the required slope. About 3,850 lbs. of Atlas Portland cement were used on the work. The greater part of this cement came to the work in bags. The sand was of excellent quality, some coming from Avon, Mass., and the rest from local pits. The best was that which came from a nearby sewer excavation, where a water-bearing sand stratum was encountered. The bulk of the stone used in the concrete came

from the hardpan excavation, and was crushed on the work. This stone was quite dirty and had to be washed before crushing.

Previous to setting up the crusher about 750 cu, yds. of gravel stones were used, brought from a local pit. These were very dirty, also, and needed to be washed.

At first everything smaller than 2½ ins. was used, but it was found that so great a quantity of dust was coming as to give the result of adding more sand to the mixture. On this account the screens were changed and a portion of the dust discharged into a separate pile, and was later used in the surfacing of the upper layer of concrete on the slopes. The stone crushed on the hill weighed about 95 lbs. per cu. ft. and had about 46 per cent. of voids. The gravel stones weighed about 111 lbs. per cu. ft. and had about 40 per cent. of voids.

Instead of barrels for measuring the proportions of sand and cement, gage boxes, without bottoms, were used. The following sizes were found convenient.

Proportions	Sand Box Size	Sand Box Vol. cu. ft.	Stone Box Size	Stone Box Vol. cu. ft.
1—2½—4	2' 9'' x 2' x 1' 8''	9.25	5' x 4' 5½''	14.80
1—3 —6	2' 9'' x 2' x 2' 0''	11.10	5' x 6' 8 ''	22.20
1—2 —5	2' 9'' x 2' x 1' 4''	7.40	5' x 6' 6⅝''	18.50
1—2½—6½	2' 9'' x 2' x 1' 8''	9.25	5' x 7' 2½''	24.05

All concrete except that on the sides was put in rather wet and rammed till it quaked. On the sides of the reservoir a drier mixture was necessary to prevent flowing down the slope. Where possible a spade was used to puddle the concrete next to the forms and a fine smooth finish was given to the work.

As to the possibility of a concrete wall being impervious to water, attention is called to the partition wall in the gate house between the water chamber and the gate chamber. This wall is 23 ft. high, 11 ft. wide, and 3 ft. thick, and there is a head of 19.5 ft. of water against it. In dry weather there is no moisture on this wall, although no more care was taken with it than with other portions of the work.

All the concrete, when laid, was kept continually wet for at least a week, and after that occasionally sprinkled until it was covered or the work was completed.

The ordinary concrete gang was made up of a sub-foreman, 2 men gauging materials, 2 men mixing mortar, 3 men turning the concrete, 3 men wheeling concrete, 1 man placing, and 2 men ramming. All the concrete was mixed and placed by hand. Two gangs were ordinarily employed, placing about 20 cu. yds. per day, each, or about 1.43 cu. yds. per day per

man. The concrete was turned at least three times before placing.

Besides the gang on the concrete three plasterers and three helpers were employed on the upper layer on the slopes.

After the banks were finished a granolithic walk, 6 ft. wide, was constructed about the top of the bank. This walk has a foundation stone about 12 ins. thick, on top of which is a concrete layer 4 ins. thick at the sides and 5 ins. thick at the middle. This concrete is surfaced with granolithic finish about 1 in. thick. The walk was laid in separate blocks, about 6 ft. square, a steel templet being used to keep adjacent blocks entirely separate. The average gang employed on the concrete of the walk was six men and a single team, while two masons and a tender did the finished surface. The average amount of work finished per day was 60 lin. ft.

There are various rather unimportant variations from this method. In regard to dimensions of blocks, in Pittsburg the blocks were made 9 inches thick and 7 feet square, the joints 3/8-inch wide at bottom and 3/4-inch at top and filled with asphalt. A half inch of Portland cement was put on as a top coat. At Albany the blocks are 7 feet square and asphalt joints are 1/2 inch wide and half the depth of the block. Blocks are made in some cases as large as 20 feet square.

In regard to proportions of materials, Pittsburg used concrete in proportions of 1, 2, 4, of Portland cement, sand and broken stone, the top coat being 1 to 1 mortar. Havana, Cuba, used two 6-inch layers of proportions 1, 3, 5. Syracuse used a 9-inch layer of 1, 2, 3, using natural cement. Special treatment is sometimes necessary, using asphalt, clay or other impervious materials in foundation or lining to prevent leakage.

CEMENT WALKS.

Some general instructions and specifications for laying cement walks are given, and they are followed by samples of full specifications from St. Louis, Pittsburg and Indianapolis as examples of the variations in specifications which produce good walks.

It is especially important in this class of work to use the best materials, carefully selected, and to exercise great care in every part of the work.

Thorough drainage of the foundation course of gravel, broken stone or cinder must be assured, and this foundation

must be at once firm and porous, and well compacted. It is well to do the excavating and filling some time before the concrete is put in, thus securing thorough setting. But cross boards should be placed on the fill and plank laid lengthwise on these to prevent packing of one portion more than another, where the wall is much used.

The thickness of the porous bed is not important if it be certain it is sufficient to insure solidity and perfect drainage at every part.

The bed should be well wet down before putting in the concrete.

Two by four inch strips should be firmly staked on edge with upper edge to grade, and braced apart to desired width with cross pieces between.

A thoroughly mixed body of concrete composed of one part cement, two parts sand and four parts gravel, pebbles or broken stone, is shoveled between the strips, having been tempered to such degree of dampness that when rammed solidly to place some water will be forced to the surface.

Sufficient concrete is used that about three-quarters inch space remains uniformly between the surface of grade and the surface of concrete. The concrete is then cut into blocks with an ax or wedge-shaped tool which leaves a V opening or groove between the blocks. The blocks should not be larger than 4x6 feet.

The position of the grooves should be carefully located on the strips or otherwise.

Finally a coat of cement mortar of one part cement and one and one-half parts sand (of excellent quality, coarse, sharp and clean), so tempered that it can be worked to a surface with a straight-edge shifted on the surface of the side strips, is applied to the surface of the concrete. A thin film of mortar is troweled on to the surface in advance of the main body, being spread over by the straight-edge.

After the straight-edge, a float is used. This is applied just as the surface film of water is being absorbed, and immediately after it a slight troweling to a smooth surface is applied. The troweler then cuts entirely through the walk in the lines of the joints already formed, with his trowel and bevels the edges of the cut or rounds them with an edging tool. The outer edges are also rounded or beveled.

The walk is then covered with sawdust, fine sand or canvas to protect it from the sun and air, and kept well wet for at least 48 hours when it may be uncovered and allowed to dry out slowly, with frequent wettings for several days. The strips may then be removed.

Do not dust the surface or trowel very long.

Inside of yards or lawns less thickness of concrete and less proportion of cement may be used.

The following, selected from specifications for cement walks prepared by Albert Moyer, of New York City, gives the opinions of a practical man upon some questions in sidewalk construction concerning which there is much discussion.

In laying a cement sidewalk keep constantly in view the fact that the form of construction is artificial stone slabs or flags, each slab subject to all the conditions surrounding artificial stone, such as careful selection of materials, thorough mixing, tamping, and seasoning, allowance in the joints for expansion, upheaval by frost, and wear. Portland cement concrete expands and contracts with temperature changes in practically the same ratio as steel. Upheaval by frost is obviated by providing an under drainage.

For drainage foundation excavate to a sufficient depth so as to get below the frost line, fill in with clean cinders or broken stone to within 4 inches of top of established grade of the pavement. Tamp well and evenly and thoroughly wet the cinders or stone.

For cement sidewalks in warm climates where freezing does not occur excavate to a depth of 4 inches below established grade of the sidewalk, tamp the ground well and evenly, omit the cinder or broken stone drainage foundation.

Screenings or crusher dust if used for wearing surface must be of crushed quartz, granite or other hard, tough stone, free from mica or foreign matter and crushed so that the largest piece will pass through a sieve of $\frac{1}{4}$-inch meshes, the particles graded in size from fine to coarse; the crusher dust to contain not over 30 per cent. of fine dust. Sand does not make as good a wearing surface as screenings or crusher dust.

Cinders or broken stone for foundation drainage must be broken so that the largest piece will not exceed 3 inches, and the smallest to be not less than 1 inch in diameter, free from dirt or other foreign matter. The cinders to be carefully selected furnace cinders. Blast furnace slag, broken as above, may also be used.

Retempering of cement mortar should never be permitted.

Do not allow any block to bear directly against any solid body, such as stone curb, building, post, manhole-rim, etc. Leave the same space (about $\frac{1}{4}$ inch) between pavement and such fixtures as is between the blocks themselves. This note applies to the base and top as designed to avoid cracks and chipping due to expansion and

contraction from temperature changes. This space can be conveniently provided for by the use of thick tar paper or felt.

Immediately cover the pavement with canvas, tar paper, or boards, raised a few inches so as not to come in contact with any part of the pavement.

After pavement has been down 15 to 20 hours, wet thoroughly with a sprinkler. Keep pavement covered for a week and constantly wet; do not let it dry for a moment at any time during the first week.

Do not put any water on the pavement until it has set hard, usually after 15 or 20 hours, then it becomes very necessary to keep the pavement wet thoroughly and continuously for as long a time as economy will permit. Artificial stone is best when kept entirely under water for at least one month. It becomes stronger and harder the longer it is kept wet; the same law applies to cement sidewalks as to artificial stone.

Do not use coloring matter unless absolutely necessary. Nearly all coloring matter reduces the strength of the mortar.

Do not lay new concrete on old concrete.

Do not spread a top coat over an old concrete base.

Cut out roots of trees that may extend under sidewalk.

Do not use a base of one brand of cement and a top surface of another; the different quality of the cement, difference in time of setting or hardening, contraction, expansion, etc., often causes top to crack from base.

GRANITOID SIDEWALKS, ST. LOUIS, MO.

The sidewalks shall be of three separate and distinct thicknesses and kinds, and shall be classified as follows: "Ordinary Single Flagging, "Extra Double Thick Flagging" and "Driveway or Entrance Flagging," and shall be laid in the different localities within the prescribed limits at the discretion of the Street Commissioner, who shall determine which of the above named kinds shall be laid.

Grading.—All grading which may be necessary to be done in repairing or constructing sidewalks in consequence of the adjustment of the grade of any pavement, or in order to protect the work, shall be made of such dimensions as shall be ordered, and all the filling required shall be spread in thin layers, and must be well rammed, so as to render it perfectly compact. All surplus earth shall be hauled away, and all borrowed earth, which may be required, shall be furnished by the contractor.

Ordinary Single Flagging.—After the grading and shaping is done a foundation of cinders not less than eight (8) inches thick shall be placed upon the sub-grade, which shall be well

consolidated by ramming to an even surface, and which shall be moistened just before the concrete is placed thereon.

After the sub-foundation has been finished the artificial stone flagging shall be laid in good, workmanlike manner.

The same to consist of two parts: 1st. A bottom course, to be three and one-half (3½) inches in depth. 2d. A finishing or wearing course, to be one-half (½) inch in depth.

The bottom course shall be composed of crushed granite and the best Portland cement, equal to the Dyckerhoff brand, and capable of withstanding a tensile strength of 400 pounds to the square inch after having been three hours in the air and seven days in water, and shall be mixed in the proportion of one part cement to three parts of crushed granite.

The crushed granite shall consist of irregular, sharp-edged pieces, so broken that each piece will pass through a three-fourths (¾) of an inch ring in all its diameters, and which shall be entirely free from dust or dirt.

The crushed granite and the cement in the above-mentioned proportions shall first be mixed dry, when sufficient clean water shall be slowly added by sprinkling, while the material is constantly and carefully stirred and worked up, and said stirring and mixing shall be continued until the whole is thoroughly mixed.

This mass shall be spread upon the sub-foundation and shall be rammed until all the interstices are thoroughly filled with cement.

Particular care must be taken that the bottom course is well rammed and consolidated along the outer edges.

After the bottom course is completed the finishing or wearing course shall be added. This course to consist of a stiff mortar composed of equal parts of Portland cement and the sharp screenings of the crushed granite, free from loamy or earthy substance, and to be laid to a depth of one-half (½) of an inch and to be carefully smoothed to an even surface, which, after the first setting takes place, must not be disturbed by additional rubbing.

When the pavement is completed it must be covered for three days and be kept moist by sprinkling.

Extra Double Thick Flagging.—After the grading and shaping is done a foundation of cinders not less than six (6) inches thick shall be placed upon the sub-grade, which shall be well consolidated by ramming to an even surface and which shall be moistened just before the concrete is placed thereon. After the sub-foundation has been finished the artificial stone flagging shall be laid in a good, workmanlike manner.

The same to consist of two parts: 1st. A bottom course to be five (5) inches in depth. 2d. A finishing or wearing course to be one (1) inch in depth.

The bottom course shall be composed of crushed granite and the best Portland cement, equal to the Dyckerhoff brand, and capable of withstanding a tensile strength of 400 pounds to the square inch after having been three hours in air and seven days in water, and shall be mixed in the proportion of one part of cement to three parts of crushed granite.

The crushed granite shall consist of irregular, sharp-edged pieces, so broken that each piece will pass through a three-fourths (¾) of an inch ring in all its diameters, and which shall be entirely free from dust or dirt.

The crushed granite and the cement in the above-mentioned proportions shall first be mixed dry, then sufficient clean water shall be slowly added by sprinkling, while the material is constantly and carefully stirred and worked up, and said stirring and mixing shall be continued until the whole is thoroughly mixed.

This mass shall be spread upon the sub-foundation and shall be rammed until all the interstices are thoroughly filled with cement.

Particular care must be taken that the bottom course is well rammed and consolidated along the outer edges.

After the bottom course is completed the finishing or wearing course shall be added. This course to consist of a stiff mortar composed of equal parts of Portland cement and the sharp screenings of the crushed granite, free from loamy or earthy substances, and to be laid to a depth of one (1) inch and to be carefully smoothed to an even surface, which, after the first setting takes place, must not be disturbed by additional rubbing.

When the pavement is completed it must be covered for three days and be kept moist by sprinkling.

Driveway or Entrance Flagging.—After the grading and shaping is done, a foundation of crushed limestone and hydraulic cement mortar shall be laid to a depth of six (6) inches on the sub-grade. The stone used in this concrete shall be broken so as to pass through a two (2) inch ring in its largest dimensions. The stone shall be cleaned from all dust and dirt and thoroughly wetted and then mixed with mortar, the general proportion being one part of cement, two parts of sand and five parts of stone. It shall be laid quickly and then rammed until the mortar flushes to the surface. No walking or driving over it shall be permitted when it is setting, and it shall be allowed to set for at least twelve hours, and such

additional length of time as may be directed by the Street Commissioner or by his duly authorized agent before the pavement is put down.

Pavement.—After the sub-foundation has been finished the artificial stone flagging shall be laid in a good, workmanlike manner. The same to consist of two parts: 1st. A bottom course to be five (5) inches in depth. 2d. A finishing or wearing course to be one (1) inch in depth.

The bottom course shall be composed of crushed granite and the best Portland cement, equal to the Dyckerhoff brand, and capable of withstanding a tensile strain of 400 pounds to the square inch after having been three hours in air and seven days in water, and shall be mixed in the proportion of one part cement to three parts of crushed granite.

The crushed granite shall consist of irregular, sharp-edged pieces, so broken that each piece will pass through a three-fourths (¾) of an inch ring in all its diameters, and which shall be entirely free from dust or dirt.

The crushed granite and the cement in the above-mentioned proportions shall first be mixed dry, then sufficient clean water shall be slowly added by sprinkling, while the material is constantly and carefully stirred and worked up, and said stirring and mixing shall be continued until the whole is thoroughly mixed.

This mass shall be spread upon the sub-foundation and shall be rammed until all the interstices are thoroughly filled with cement.

Particular care must be taken that the bottom course is well rammed and consolidated along the outer edges.

After the bottom course is completed the finishing or wearing course shall be added. This course to consist of a stiff mortar composed of equal parts of Portland cement and the sharp screenings of the crushed granite, free from loamy or earthy substances, and to be laid to a depth of one (1) inch and to be carefully smoothed to an even surface, which, after the first setting takes place, must not be disturbed by additional rubbing.

When the pavement is completed it must be covered for three days and be kept moist by sprinkling.

CEMENT SIDEWALKS, PITTSBURG, PA.

Pavements of this class shall consist of a foundation of coarse cinder, or broken stone, six (6) inches deep; a layer of Portland cement concrete, three (3) inches thick, and a wearing surface of Portland cement mortar, one (1) inch thick, making the total thickness of the completed pavement at least ten (10) inches.

The broken stone or cinder to be used in the foundation shall be of approved quality, broken so that the largest dimension of any piece will not exceed three (3) inches, nor the smallest dimension of any piece be less than one (1) inch, and must be free from dust, dirt or other foreign matter.

Broken stone for concrete shall be a good, hard stone that will not be affected by the weather, broken so that the largest dimension of any stone shall not exceed one and one-half ($1\frac{1}{2}$) inches, nor the least dimension of any stone be less than one-quarter ($\frac{1}{4}$) of an inch, and must be free from dust, dirt or other foreign matter.

Gravel used for concrete shall be washed river gravel of such sizes that the greatest diameter of any pebble will not exceed one and one-half ($1\frac{1}{2}$) inches, nor the least dimension of any pebble be less than one-quarter ($\frac{1}{4}$) of an inch, and must be free from dust, dirt or other foreign matter.

The sand shall be of the best quality of coarse, sharp, clean Allegheny river sand, free from dust, loam or other foreign matter, or a sand equal in quality there to.

Portland cement shall be equal in every respect to that hereinbefore specified under the heading "Specifications for Cement." [See the chapter on "Specifications for Cement" for the same.]

The screenings to be used in the wearing surface shall be crushed quartz, granite, Ligonier stone or other stone equal in quality thereto, crushed so that the largest piece will pass through a sieve of one-quarter-inch meshes.

Water shall be fresh and free from earth, dirt or sewage.

The width of the pavement shall be such as the director may specify.

The foundation shall be of cinder or broken stone as hereinbefore specified, and shall be drained to the curb ditch by 10-inch by 12-inch stone drains placed every 25 feet along the line of the walk.

The concrete shall consist of 1 part in volume of Portland cement, 3 parts of sand and 6 parts of broken stone or gravel.

The cement or sand in the specified proportions shall be thoroughly mixed dry on a tight platform with shovels or hoes until no streaks of cement are visible.

Water shall be added to the sand and cement, mixed in accordance with the foregoing directions, in sufficient quantities to produce a mortar of the desired consistency, and the whole thoroughly mixed with shovels or hoes until a homogeneous mass is produced.

The mortar, prepared as hereinbefore specified, shall be spread upon the platform, the proper quantity of broken

stone or gravel, after having been thoroughly wetted, shall then be spread over the mortar and the mass thoroughly turned over with shovels or hoes not less than three (3) times, or until every pebble or piece of broken stone is completely coated with mortar.

Water shall be added by sprinkling during the process of mixing if required to secure a better consistency.

All surfaces on or against which concrete is to be laid shall be thoroughly cleaned and dampened by sprinkling with water just previous to placing the concrete.

The concrete shall be evenly spread upon the foundation, as soon as mixed, in a layer of such depth that after having been thoroughly compacted with rammers of approved pattern it shall not be in any place less than three (3) inches thick, and the upper surface of it shall be parallel with the proposed surface for the completed pavement.

The slab or flag divisions shall be formed by cutting the concrete clear through, on the required lines, as soon as laid. The space made by the cutting tool shall be immediately filled with dry sand and well rammed.

Concrete should not be mixed in larger quantities than is required for immediate use, and no batch shall be larger than can be made of one barrel of cement with the proper proportions of sand and stone.

Concrete shall not be dropped from too great a height or thrown from too great a distance when being placed upon the work.

The wearing surface shall be composed of one part in volume of Portland cement and two (2) parts of screenings of the quality hereinbefore specified.

The cement and screenings in the specified proportions shall be thoroughly mixed dry, on a tight platform, with shovels or hoes, until no streaks of cement are visible.

Water shall be added to the screenings and cement, mixed in accordance with the foregoing directions, in sufficient quantities to produce a mortar of the desired consistency, and the whole thoroughly mixed with shovels or hoes until a homogenous mass is produced.

The mortar while fresh, shall be spread upon the concrete base before the latter has reached its first set, in such quantities that after being thoroughly manipulated and spread over the concrete it will make a layer one inch thick, conforming to the required grade and cross-section.

A coating of equal parts of Portland cement and dry, fine sand or screenings thoroughly mixed, shall be swept over the surface and the surface dressed and smoothed. On steep

grades the top dressing shall consist of coarse granite or Ligonier stone screenings and cement.

The surface shall then be cut into flags, the markings to be made directly over the joints in the concrete and cut clear through the wearing surface.

The flags shall then be trued up and marked all over, with the exception of a border of about an inch in width along the edges, with a toothed roller.

The pavement shall be kept moist and protected from the elements and travel until it has set.

Entrances from adjoining streets or walks to all private or public premises shall be preserved by the contractor.

The completed pavement shall, unless otherwise ordered, have a rise of one-quarter (¼) of an inch to the foot rising from the curb.

Board or timber forms shall be provided by the contractor to mold the concrete and mortar to the required shape, and shall be left in place until the concrete or mortar is set.

Retempering of concrete or mortar will not be permitted, and mortar or concrete that has begun to set before ramming is completed shall be removed from the work.

Concrete or mortar that fails to show a proper bond or fails to set after, in the opinion of the director, it has been allowed sufficient time, shall be taken up and replaced with new concrete or mortar, of the proper quality, by the contractor.

If at any time during the guarantee period any cracks, scales or other defects develop in the pavement, the pavement at that point shall be taken up and relaid with new materials, in accordance with these specifications, by the contractor.

CEMENT SIDEWALKS, INDIANAPOLIS, IND.

1. Stakes will be set by the engineer to define the line of one edge of the walk, and the grade marks will indicate the top of the walk at said time. The transverse slope of the walk will be one-fourth inch per foot, and will be determined with level and grade board made according to drawing in engineer's office.

2. The sidewalk shall be graded to the width as shown on plan for the entire length of the improvement, including all wings and crossings, as shown on plan, and sixteen inches below the finished surface of the walk. The grading must be smoothly and neatly done, all large stones, bowlders, roots, sods and rubbish of every description being removed from the grade, and the entire work must be made to conform fully to the profile and the grade of the walk when finished.

Soft, spongy or loamy spots in the sub-grade must be taken out and refilled with good material and the grade solidified by ramming.

3. Trees shall not be injured, cut down or otherwise disturbed except by order of the engineer. Roots of trees which are not removed, but which are contiguous to the line and grade of the walk or in any way interfere therewith, must be trimmed and cut away as the engineer shall direct, and where the engineer directs the stones shall be fitted to the trees and roots covered with earthenware half-pipes. Any tree removed must be grubbed for the entire width of the sidewalk and also its roots that rise above the level of the sub-grade. No extra compensation for such work will be allowed.

4. Upon the sub-grade thus prepared and after inspection and acceptance of the same, a foundation of clean creek or pit sand and fine gravel, or broken stone, in such proportions as, when rammed, will form a solid and compact mass, shall be spread to a uniform depth of twelve inches, all to be rammed and tamped until it presents a hard, smooth surface. It shall be sprinkled with water as required, enough remaining to render the surface as moist as the concrete at the time the latter is laid.

5. Wooden frames four inches in height will be placed in the manner necessary to outline both external edges of the walk accurately, the top of the frames being located to coincide with the established grade of the walk. Gauges must be used to render surface of foundation layer and of concrete parallel to the top of the walk. Concrete will be made as follows: One measure of Portland cement of the kind elsewhere specified for sidewalks, and two measures of clean, sharp sand shall be mixed thoroughly, while dry, and then made into mortar with the proper amount of water as determined by the engineer; broken stone or gravel not over one inch in any dimension, thoroughly cleansed from dirt and dust and drenched with water, but containing no loose water in the heap, will then be mixed immediately with the mortar in such quantities as will give a surplus of mortar when rammed. This proportion, when ascertained, will be regulated by measure. The engineer may accept a clean, natural mixture of sand and gravel if it is uniform and contains no dirt or other foreign matter, or stones larger than above specified. The proportions will be one part of cement to five parts of the mixture, to be mixed dry, the water being added afterward. Each batch of concrete will be thoroughly mixed, and the engineer may prescribe the number of times it shall be turned over, wet and dry, to accom-

plish this result. In general it shall be turned (or cut) four (4) times dry and three (3) times wet. It will then be spread to fill the frames even full and be at once compacted thoroughly by ramming until free mortar appears on the surface and until a one and one-fourth ($1\frac{1}{4}$) inch gauge, furnished by the inspector, will pass over the concrete. It is the intention that the surface of the concrete, when thoroughly rammed, shall be at least one and one-fourth ($1\frac{1}{4}$) inch below the top of the frame. The whole operation of mixing and laying each batch of concrete will be performed as expeditiously as possible.

6. After each batch of concrete is laid, as required, it shall be immediately covered with the wearing surface. Any portion of the foundation which has been left long enough to have any appearance of setting shall be taken up and relaid before the top is put on, and under no circumstances will concrete be allowed to remain over night before top is put on. The wearing surface or top shall be composed of five parts of the same kind of cement used in the concrete and seven parts of clean, sharp sand, thoroughly mixed dry and made into mortar with the proper amount of water as determined by the engineer. It shall be evenly and compactly spread to the finished surface of the walk and made smooth and even by troweling and floating. The top and concrete foundation shall be cut into blocks of dimensions approved by the engineer, forming an expansion joint between adjoining blocks. The pavement shall be properly fitted around all fixtures in the sidewalks, the edges of the pavement to be beveled from top surface to bottom of concrete with the material used on the top.

7. Coloring matter of quality and quantity approved by the engineer will be required for the top surface. On business streets the engineer may require the surface to be carefully rolled with a toothed roller when the finish is completed.

8. Where walks of any description that now exist on the street shall be accepted by the Board of Public Works or the engineer they shall be relaid if the engineer deems it necessary, to the grade and line established, and if the price therefor is not fixed in the contract, it shall be determined by adding 15 per cent. to the actual cost of the work as determined by the engineer. Similar procedure will be taken for extra work in resetting area ways and similar structures to grade and line. When a driveway occurs in the line of the walk the walk will be increased in thickness and laid according to plans furnished by the engineer, the additional expense to be paid by the owner.

9. All blocks used shall be perfect and of good quality in

all respects, free from cracks, warps and similar imperfections. Special care shall be taken to protect the walk at night. If found not to comply with the specifications in any respect at any time up to the end of the guarantee period they shall be taken out immediately and replaced by the contractor at his own expense.

10. A list of Portland cements which have been tested in the laboratory and found satisfactory for use in the construction of cement walks will be found in the office of the city engineer.

11. Embankments shall be formed of compact earth free from large stones or perishable materials and shall be raised to such a height as to conform to the grade and line after such embankment shall have become well settled by properly tamping, ramming or rolling the same.

12. The lawns shall be graded to conform to walk and curb grades and dressed with fine earth, raked and left smooth. If sodding is specified the lawns shall be sodded with blue grass sod, free from weeds and such as to meet the approval of the city engineer. All joints will be broken in laying and the sod shall be laid to a uniform and even surface. The sodding must be kept sprinkled until such time as the entire improvement is accepted by the city. If the lawns are already in grass they shall be left in proper condition satisfactory to the city engineer and any unnecessary damage shall be repaired. Traffic on the street must not be interfered with any more than is necessary, and the walk must be laid in sections which will interfere as little possible with pedestrians. As soon as the walk has been completed in front of any lot, the contractor shall clean the street in front of completed sidewalk of all surplus material, cement, sand, gravel, barrels, etc., used in its construction, and permanently improved streets shall be kept clean in front of completed sidewalk until accepted by the city.

TYPICAL SIDEWALK SPECIFICATIONS.

The following notes on typical specifications for concrete sidewalks, by Sanford E. Thompson, Asso. M. Am. Soc. C. E., in Cement, are of interest and value in this connection:

The specifications for the construction of concrete sidewalks in various localities throughout the United States show considerable uniformity, and yet vary sufficiently so that an outline of methods employed in different places may be of interest.

It is not intended to draw from these fragmentary notes a set of ideal specifications, for the difference in construction

followed in different cities may be due partly to the character of the soil upon which the walk is to be laid, partly to the climate—that is, to the extent to which the sidewalk may be affected by frost, and in part to the kinds of material which can be most readily obtained. The amount of wear which the pavement is to receive may also influence the thickness or the construction. It is believed that the data given, however, will furnish hints of value to those interested in this line of work.

In the cities selected to illustrate the different methods of paving throughout the country scarcely two of them designate concrete sidewalks in their specifications by the same terms. They are variously called "Artificial Stone Sidewalks," "Portland Cement Flag Stonewalks," "Granolithic Cement Concrete," "Cement Sidewalks," "Portland Cement Concrete Sidewalks," "Artificial Stone Flagging," or simply "Artificial Walks."

The styles of construction in the several cities vary less than the names by which the sidewalks are designated. The following table gives a meagre outline of the dimensions and the character of the materials employed in several cities selected in different parts of the United States:

City.	Foundation. Thickness	Foundation. Material	Base Thickness	Base Proportions.	Wearing Surface. Thickne's	Wearing Surface. Pro. por. Cem. Sand	Dry Coat. Pro. por. Cem. Sand	Size of Blocks.	Guarantee Yrs
Boston	12″	Broken stone, gravel or cinders	3″	1:2:5	1″	1:1		Bet. 3½—6 ft. sq.	10
Rochester, N. Y.	6″	Sand, gravel, broken stone or cinders	**	1:5	1″	2:3			3
Philadelphia, Pa.	3″	Sand, gravel, broken brick, stone or cinders	3″		2″	1:2	1:1		
Washington, D. C.	0		4″	1:2:5	1″	2:3	1:1		5
Chicago, Ill.	0 or 12″*	Cinders	4¼″ av.	1:2:5	¾″	1:1		5 ft.×6 ft.	10
Milwaukee, Wis.	4″	Cinders or broken stone	2½″	1:3:5	1″	1:1		Bet. 24—36 ft. sq.	
St. Louis, Mo.	8″	Cinders	3½″	1:3	½″	1:1			1
Omaha, Neb.	4″	Gravel, slag or stone,	3″	1:2:4	1″	1:2	3:1		5

* 12″ cinders required where the soil is not clean sand.
** Specified for each contract.

This table merely illustrates some of the differences in construction. To show more clearly some of the special methods followed, the various divisions of the work will be considered more in detail, using for the sake of uniformity the same cities classified in the table.

Foundation.—In all of the cities the specifications require that excavation, or fill, shall be made to a definite sub-grade, and that all insecure or spongy material below this sub-

grade shall be dug out and refilled with gravel or its equivalent and thoroughly puddled, rammed or rolled. Foundation to be placed upon this sub-grade varies considerably in different localities, both in the character of the material and the thickness of the layer. The character of the sub-soil and the climate influence the thickness necessary for good work. Many places require that the material used shall pass through a $1\frac{1}{2}$ or 2-inch ring. All cities require that it shall be thoroughly rammed, and sometimes puddling is specified.

Concrete Materials.—Portland cement is always required, and in general the selection of the brand is limited to the best German or American cements. Some cities specify only German Portland; others give a list of German and American Portlands from which selection may be made; while others give representative brands and allow some discretion to the superintendent.

The specifications for the cement in most of the cities require that when sifted through a sieve of 10,000 meshes per square inch there shall not be left over 10 per cent. residue. St. Louis allows 15 per cent. residue, and Chicago allows only 8 per cent. In addition to this test, Boston and Cambridge, Mass., require that when sifted through a sieve of 32,500 meshes per square inch, there shall not be left over 45 per cent. residue. Chicago requires that, when mixed with 20 per cent. of water by measure, the initial set shall not take place in less than 45 minutes. Chicago also requires that the cement shall meet the requirements of the "boiling" test.

For tensile strength part of the cities require 50 pounds per square inch for neat briquettes which have remained twenty-four hours in air and six days in water, while others require 40 pounds, with the same test. Some of the cities require an additional test of cement mixed with sand or screenings. In Chicago one part of cement and four parts fine granite screenings, exposed one day in air and six days in water, must show a tensile strength of 200 pounds per square inch and a gradual increase of strength of 15 per cent. at the end of twenty-eight days. In the District of Columbia the specifications for the cement must conform to the current specifications for the Engineering Department of the District of Columbia.

The sand for use in the base is generally a clean, sharp sand. In Chicago clean torpedo sand is specified, ranging from $\frac{1}{8}$ inch size down to the finest. Voids there are not to exceed 30 per cent., and the weight must not be less than 190 pounds per cubic foot. Washington requires that sand shall range from fine to coarse, and shall be free from im-

purities, but may show when shaken with water and after subsidence not more than 3 per cent. by volume of silt or loam.

The kind of material used for the coarse stuff of the concrete base varies considerably in different places. Boston requires that it shall consist of sharp gravel or broken stone, not exceeding ¾ inch in size. Rochester, N. Y., specifies that fine, clean gravel, not over ¾ inch in size, shall be delivered on to the work and sifted through an inclined screen having 16 meshes per square inch. For the base of the pavement is taken the clean, medium, fine gravel from the front of the screen, and for the wearing surface is used the sand behind the screen. In Philadelphia the stone must be solid trap rock, or other approved hard slag or stone, and must pass through a 1½-inch ring. Chicago specifies crushed limestone not more than 1 inch in any direction. Milwaukee states that there shall be used cubical broken limestone not over ¾ inch in any direction. Omaha allows broken stone or slag up to 1½ inch in greatest diameter.

The material for the wearing surface also varies largely in different localities. Boston requires one part of fine crushed trap or granite rock, screened through ¼-inch mesh, or one part of Newburyport sea sand to one part of Portland cement. In Philadelphia two parts of crushed granite to one part imported Portland cement are used, and the granite must be free from dust and of such size that the largest particles shall pass through a ½-inch sieve. In Washington the same sand is used for the surface coat as is used for making the concrete of the base. Chicago uses one part Portland cement to one part torpedo gravel. Milwaukee requires one part Portland cement to one part finely crushed granite, which shall have square or cubical fracture and not measure over ¼ inch in any direction. Omaha requires substantial stone or granite which will pass through ½-inch mesh screen, mixed one part cement to two of crushed stone.

A few other cities require that dry cement shall be floated on top of the surface when finishing. In Philadelphia this dryer is to be one part cement to one part sharp flint sand. In Omaha, Neb., three parts Portland cement to one part sand.

Concrete Curb.—In Boston the foundation for a curb is 12 inches thick and consists of broken stone, screened gravel or soft coal cinders thoroughly rammed. Upon this foundation is laid concrete 12 inches wide and 8 inches deep, and before this is dry a layer of concrete 7 inches wide at the bottom and 11 inches deep is placed, tapering on the outside to 6 inches wide at the top. The inside face is vertical. On

the face and top a 1-inch wearing surface is laid. The exposed face is brushed with a little brush before becoming entirely dry.

Combined Curb and Gutter.—In Milwaukee a combined curb and gutter is often laid. This consists of a curb 5 inches wide at the top, having 7 inches of face above the gutter and a gutter 15 inches in width. It is constructed in alternate sections of stone 6 feet in length. The face corner of the curb is rounded to a radius of 1½ inches. The gutter flag is laid to a pitch corresponding to the crown of the street. Excavation is made to a depth of 11 inches below the gutter flag, except where a sub-soil drain is required, when a 3-inch drain tile is placed below this sub-grade. The foundation consists of cinders or broken stone 6 inches thick, and upon this is laid the concrete core of the combined gutter and curb, which is 4 inches thick on the bed and 4 inches in width in the molds set for the curb. A 1-inch finishing layer is placed upon the surface of the gutter and the face of the curb before it is dry, troweled as usual, and then finished with a broom.

Driveways.—Driveways are sometimes made of the same thickness as the regular sidewalk and sometimes thicker. In Rochester, N. Y., the total thickness for driveways is 6 inches, 4½ inches of this being base and 1½ inches the top. In this city the contract price for a driveway is 1½ times the contract price for the walk. Surfaces of driveways are usually marked off in 6-inch squares.

Clauses.—Several of the cities have special clauses which are of interest. Some of these apply particularly to the locality of the city, while others might generally be adopted to advantage.

In Boston the specifications require that no work shall be done after November 15th, or in freezing weather. In this city a metal plate bearing the name and address of the contractor and the date of the year in which the sidewalk is laid must be placed in each sidewalk. Boston requires that no adjoining blocks shall be laid within six hours of each other, and the requirement is also made that, where spalling, splitting off or other defects occur after completion, the entire block or division must be replaced with a new block or division, no patching being allowed.

Philadelphia specifies that no concrete shall be kept over half an hour after mixing before it is laid.

Washington specifications state that only one barrel of cement shall be used to a batch. In Washington, after leveling off the surface of the finishing coat or wearing surface, it

is beaten with wooden battens to break any air cells and make surfacing perfectly solid. In long walks transverse expansion pieces of dressed white pine 1 inch by 6 inches are provided at intervals of about 200 feet.

St. Louis requires that the bottom course, which is 3½ inches thick and is composed of one part Portland cement to three parts of crushed granite, shall receive no less than one barrel cement to each 36 square feet of sidewalk.

In most of the cities a uniform thickness of walk is required, but in Chicago the thickness is 5½ inches in the center, sloping to 4½ inches at each edge. Chicago requires that the walks shall remain at the original grade for ten years, and thus makes its contractors responsible for the foundation. Many cities build their walks with a slope of about ⅜ inch to the foot toward the gutter. A few specifications require that the walk shall be covered with moist sand until the cement is set; some specify that the length of time shall be three days. In some cases it is specified that the walks shall, or may, when required, be rolled with a metal roller to give an indented finish. In one or two of the cities the authorities keep back 10 per cent. of the contract price to have a guarantee that repairs will be satisfactorily made. In the District of Columbia this amount may be invested in Government bonds if desired by the contractor.

Cement sidewalks may be laid over area ways by placing steel beams of sizes suitable for the span and weight, and ordinarily about three feet apart and laying the walk, arched on its under surface, in the usual manner, wooden centers being used to hold the concrete in place until it has set. Ordinarily the thickness at the crown of the arch will be about four inches, and at the supports sufficient to rest on the bottom flanges of the beams, the finishing coat being carried over the tops of the beams so as to form a uniform level surface. In some circumstances tie rods to prevent spreading of the beams from the thrust of the arches will be necessary.

It is a common practice in England to make slabs for concrete walks, using, for example, 1 part Portland cement to 3 parts crushed granite passing a 3-16-inch sieve, mixed thoroughly, dry, and with the smallest possible amount of water. The molds are preferably metal lined, true in shape, with well defined arrises, oiled to prevent sticking. By one process the concrete is deposited by small shovelfuls in the mold while it is rapidly shaken up and down in a machine. As the material

is shaken and troweled into place the moisture rises to the surface, which is finished smooth and even. Six minutes' time is taken in making the slab, which then sets for two days in the mold and seven to nine days in the air, when it is immersed for from seven to nine days more in a bath of "soluble silica" made from flint and caustic soda. Hydraulic pressure is also used in pressing the concrete into the molds, in which case twenty-five slabs can be turned out in an hour.

CEMENT CURBING, INDIANAPOLIS.

The specifications for cement curb and gutter in Indianapolis, under which over fifty miles have been laid, are as follows:

1. The curb stone must be of the best quality of granite, blue oolitic limestone, stratified limestone or Berea sandstone, Parkhurst or other artificial combined curb and gutter.

2. The contractor must make good any disturbance of sidewalk or lawn and any unnecessary disturbance of trees in setting curb. Special construction to protect trees shall be made when deemed necessary by the engineer.

3. The curb shall be under the same guarantee as the street surface.

4. Combined curb and gutter shall be set to stakes set by the engineer at points necessary to accurately designate the line and grade of the proposed curb and gutter and any variation in the height of the same between grade points and catch-basin inlets.

5. The material to be used shall be Portland cement as specified in "Class A" for sidewalks (see Cement Sidewalk Specifications), clean, sharp, coarse sand, crushed granite and granite screenings with no stone with any dimensions over one inch.

6. The combined curb and gutter, whether Parkhurst or otherwise, shall be constructed upon a two-and-a-half-inch concrete foundation before the concrete has become firmly set, so as to secure complete adherence between the two. The combined curb and gutter shall consist of a curb six (6) inches wide at the top and generally seven (7) inches high above the gutter where it joins the curb, and a gutter sixteen (16) inches wide and six (6) inches deep so constructed that the curb and gutter shall be monolithic. It will be composed of a concrete core or backing faced with one inch in thickness of facing or finishing mortar as shown by drawing on file in the office of the City Engineer. The core or backing will be constructed of concrete composed of:

Portland cement ....1 part
Clean sharp sand............................$2\frac{1}{2}$ parts
Crushed granite, crushed bowlders, or screened
gravel ....5 parts

The crushed granite or bowlders shall be clean and sound, broken so that every fragment will pass through a screen with meshes one square inch, and all dust and particles smaller than a grain of corn shall be screened out. The Portland cement and sand shall be first well mixed dry and then sufficient water added and the mixing continued until mortar of uniform composition and of the proper consistency is produced.

The crushed stone shall be added and thoroughly mixed with the mortar until every fragment of stone is coated with mortar. The concrete will then be put in place and well compacted by ramming. The whole operation must be completed before the mortar begins to set.

The facing or finishing mortar shall be composed of

Portland cement ....2 parts
Clean sharp sand ....1 part
Crushed granite ....3 parts

The crushed granite screenings shall be made from hard, sound stone, and the fragments shall be of such size that all will pass through a screen having one-fourth inch meshes, and all fine dust shall be screened out. The facing mortar shall be mixed in the same manner as the concrete described above.

If ordinary artificial combined curb and gutter is used it shall be constructed as specified, and there shall be no projections on back and bottom, nor shall there be any other infringement on the Parkhurst patent. If Parkhurst curb is used a projection of one inch on back and bottom according to Parkhurst patent shall be constructed as approved by the City Engineer.

7. Concrete, immediately after being mixed as above specified, shall be placed in the necessary forms or molds as rapidly as it can be thoroughly compacted by ramming with a twenty-pound rammer until the molds are full and the curb is ready for surfacing.

8. The entire exposed surface of the curb and gutter shall be faced by floating and troweling a coat of neat cement so as to give it a uniform color throughout.

9. The work shall be carried on uniformly and the whole curb and gutter completed while in a soft and plastic state, so that it will become a homogeneous solid when set.

10. Sections in the curb shall not be less than seven feet long.

PARKHURST COMBINED CURB AND GUTTER.

First. The gutter and curb must be so combined as to form one continuous and solid stone, and the combined curb and gut-

ter stone must be of the same general dimensions shown in diagram on file.

Second. No additional allowance will be made for round corners, nor for cutting holes for catch basins, and the price paid for curbing shall be per linear foot in place complete.

Third. The materials to be used shall be Portland cement and clean, sharp, coarse sand, medium-sized gravel or stone crushed to the proper size, all subject to the approval of the City Engineer.

Fourth. One part Portland cement, 2½ parts sand and 5 parts gravel or crushed stone, shall be used in the backs and bottom part of the curb. The exposed surface of both curb and gutter shall be faced two (2) parts Portland cement and three (3) parts fine crushed granite or trap rock, and sand sufficient to make a smooth and even finish, but not to exceed one (1) part.

Fifth. Portland cement must be used which shall stand a tensile strength of 300 pounds per square inch after seven days, six days in water and one day in air, and which shall have a crushing strength of 2,000 pounds per square inch after having been immersed in water seven days, and then exposed to the air thirteen days, and the contractor shall furnish for testing a sample of each and every barrel of cement to be used in the construction of artificial stone curb and gutter whenever the engineer may request it.

Sixth. The material—of the quantity and in the proportions herein specified—shall be mixed dry, and until the mixture has an even color. Water shall then be added slowly while the materials are being constantly and thoroughly mixed, and stirred until an evenly tempered and complete mortar suitable for molding is obtained. The mortar thus obtained shall be immediately placed in the molds as rapidly (but not more rapidly) as it can be thoroughly rammed until the mold is full and the top is finished in the manner herein specified.

Seventh. The entire exposed face of the curb and gutter shall be faced by floating and troweling, so as to give it a uniform color throughout.

Eighth. The curbing is to be set to the true line and grade of the street, on a bed of six inches of fine gravel, sand or broken stone, or cinders thoroughly tamped. At the street and alley corners the curb to be made on a curve of such radius as the engineer may direct, with true and even joints, and to be of the same description and set in the same manner as the curb before described.

STREET CROSSINGS AND DRIVE PAVEMENTS.

Excavate street 6 inches below grade line if sub-stratum is

gravel, sand or porous soil; if clay or an impervious soil, excavate 4 inches more and fill that with cinders, gravel or broken stone. Thoroughly roll to proper section, lay sub-drains of 3-inch tile inside each curb line. Pavement is laid in two courses: 1st layer, 4 inches thick, consists of 1 part Portland cement and 4 parts clean gravel or broken stone and sand. Proportion of gravel to sand, 2 to 1. Materials are thoroughly mixed by machine; just enough water being added so that when well rammed water will show at surface.

Second layer, or top, 2 inches thick, which takes the wear, consists of equal parts Portland cement and clean, sharp sand or crushed granite, including all grains to the size of a pea. Only the best of cement should be used for this purpose. The top layer is thoroughly rammed. Both bottom and top layers are divided during construction into rectangular blocks about 5 feet square, with edges neatly finished. The joints of blocks coming directly over pipes are made like the keystone of an arch, so they can be lifted up without disturbing neighboring blocks, when repairs to pipes are necessary. To secure a positive foothold for horses, the surface can have v-shaped grooves 1 inch wide and 3-16 inch deep, 4 inches apart and running at right angles with the street. Surface should be finished with an ordinary plasterer's wooden float. Curbs are part of outer blocks and consist of 1 part cement to 3 parts fine gravel. Materials for one square yard equal 144 pounds cement and 3 cubic feet of gravel.

CEMENT ROADWAYS IN RICHMOND, IND.

The portion of the specifications for concrete street pavements in Richmond, Ind., H. L. Weber, City Engineer, which refers directly to the construction of the roadway, is as follows:

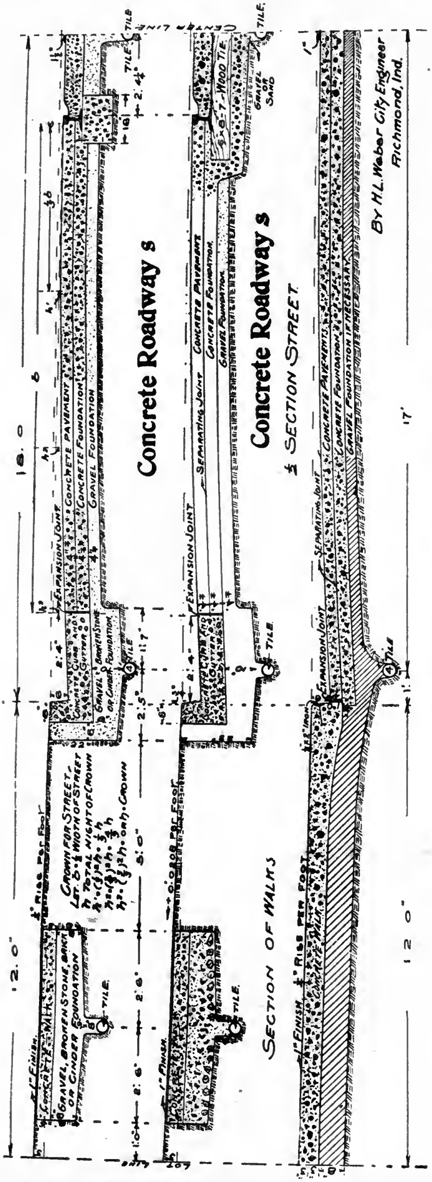
The sub-grade will be thoroughly rolled, leveled and re-rolled until it is true to grade and cross-section of the finished roadway, and from 8 to 12 inches below the surface of the street, as the case may be.

If found necessary for sub-drainage, upon the sub-grade place 3 or 4 inches of gravel, thoroughly wet and consolidated by rolling or ramming, or both.

Upon this gravel foundation will be placed a layer of concrete 4 to 5 inches in thickness and finished to a true crown and grade, parallel to the finished street surface and 3 to 4 inches below the same. This will constitute the foundation for the cement roadway.

When sufficiently strong to sustain the roadway, the surface of the concrete foundation will be covered with a coating of

fine sand, raked off with a flat board rake, by hand, so as to remove all sand except that which may remain in low places and voids in the concrete foundation.



SECTIONS OF CONCRETE ROADWAYS, RICHMOND, IND.

Upon this will be placed a layer of thin tar-paper (or other

suitable paper) or material to act as a separating joint.

Upon this will be laid the concrete pavement 2 to 3 inches thick, in sections the full width of the street and —— feet in length, with expansion joint next the gutters and ends.

This roadway will be composed of 1 part cement, 2 parts sand, 3 parts gravel and 3 parts crushed stone, mixed with water to form a rather wet mixture.

Upon this will be placed the wearing surface, one inch thick, composed of 1 part cement, 1 part clean, sharp sand, and 1 part clean stone or granite screenings, mixed with water to form a rather wet facing mixture.

The wearing surface will be deposited in two layers, one-half inch thick, the first to be thoroughly rammed to insure perfect contact; the second applied immediately after, and thoroughly troweled and worked over, and made to conform to the finished surface of the street by the use of the proper forms.

When sufficiently hard, the surface to be floated and steel troweled, and, lastly, raised with a cork float, and when finished must be true to grade and cross-section.

All concrete must be machine made, or thoroughly mixed by hand, as the Engineer may direct.

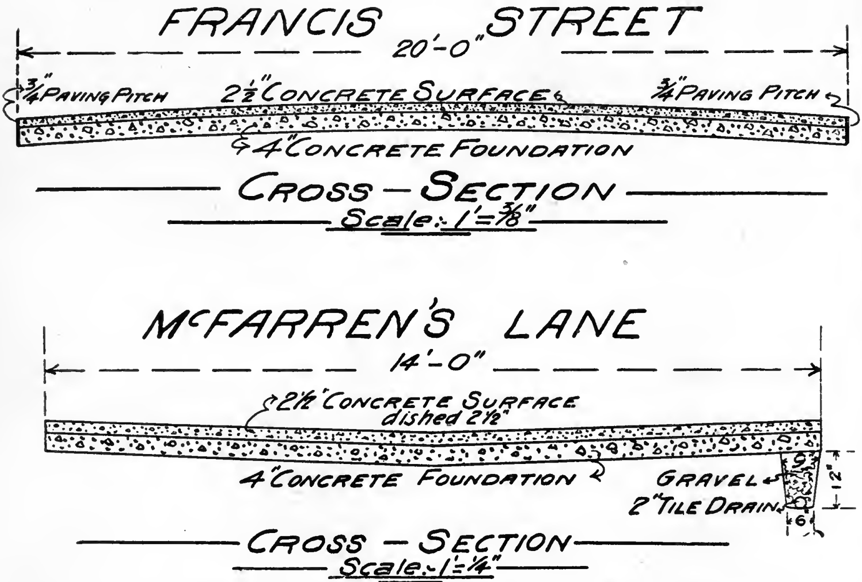
CONCRETE STREET PAVEMENTS IN TORONTO, ONT.

The concrete street pavement in the street railway tracks on King street, Toronto, Ont., was laid in 1899 in the following manner:

The concrete was composed of 1 part of cement, ½ part of sand and 2 parts of crushed granite. The cost was from 65 to 75 cents per square yard and the work was carried out by the City Engineer's Department. Next to each rail was placed a row of paving blocks laid as stretchers. Owing to the very large amount of traffic, this pavement has not proved entirely successful and had to be repaired in 1902. The pavement cracked near the rails and the constant traffic broke up the surface. This disintegration was probably due, to some extent, to the settlement of the rails. A similar pavement on a residential street has given good satisfaction.

Francis street, which is a short thoroughfare subjected to a great deal of trucking, was paved with concrete in 1903, the foundation being composed of 1 part of Portland cement, 3 parts of sand and 7 parts of broken stone, which is a similar foundation to that used for asphalt or brick pavements. Before the foundation had time to set, a 2½-inch surface of what is called granolithic concrete was put on. This forms the wearing surface and consists of 1 part of cement, 1 part of sand and 3 parts of crushed granite, and is marked off in blocks 5 inches

by 12 inches, which gives it somewhat the appearance of a scoria block pavement. Concrete walks, with curb, were laid on this street previous to the concrete pavement, and expansion joints were therefore provided throughout the entire width of the pavement by leaving an opening one inch along each



SECTIONS OF CONCRETE ROADWAYS, TORONTO, ONT.

curb, paving pitch being run into it until the opening was completely filled. Longitudinal expansion joints were also provided by leaving an opening three-quarters of an inch wide through the pavement, the space being filled with pitch. It would have been better to have made the longitudinal expansion joints only one-half inch wide, as it is noticed that heavy traffic has a slight tendency to break away the concrete pavement at these points. With this exception, the pavement is in very good condition, no cracks being visible. The cost of this pavement was $1.74 per square yard, the work being carried out by the City Engineer's Department.

A similar pavement was laid in 1904 upon McFarren's lane, but it was dished to the center. This street is not subjected to as heavy traffic as Francis street. It cost $1.92 per square yard, the work being done by the City Engineer's Department.

PREPARATION OF CONCRETE FLOORS.

For concrete floors the proportions may be as follows:

One part Portland cement, 3 parts of clean, sharp sand and 5 parts of stone, broken small enough to pass through a 2-inch ring. In preparing the concrete the sand and broken stone must be carefully washed clean immediately before being used. Then the cement, sand and broken stone are mixed together and an additional amount of water added by means of a spray to form a pasty matrix, the whole being well worked over and incorporated and immediately deposited in position. It must be well tempered. In heavy work the layers should not exceed 12 inches in thickness, and should be allowed to set for 24 hours before the succeeding layer is deposited.

Basement floors are usually finished with a ½-inch coat of Portland cement in the proportion of two parts cement to one part of fine, clean, white sand, and finished with a floated surface; but for heavy work the coat should be one inch in thickness.

The body of the concrete should not be allowed to dry before the finishing coat is applied.

Cement expands and contracts with changes of temperature in the same way as iron, wood, sandstone and other materials. From this cause, if the necessary care has not been taken in the work, cracks will result, especially in wide surfaces. These may be avoided by dividing the flooring into smaller blocks, which should not exceed 4 to 5 square yards in area, and should be separated by strips of tar paper or by sand joints ⅜ inch in width. The joints in the concrete must correspond with those cut in the surface layer. The division of the work into blocks is also to be recommended in concrete walls and curbs.

If necessary, lay weeping drain round the inside of all outside walls, fill in over drain with brick or stone chips; then level off the bottom of cellar to an even surface and fill in 4 inches or 6 inches of broken stone, bricks or cinders, making the excavation enough deeper to allow this foundation below the concrete work described.

FLOORS FOR WET CELLARS.

When water flows into a cellar and cannot be drained by terra cotta pipe it is necessary to make a very strong floor to resist the outside water pressure.

1st. Prepare the bottom of the cellar in the shape of a shallow dish with the lowest part in the center.

2d. Dig a shallow well in the center and lead all the water to this well by cutting shallow ditches from the four corners of the cellar and laying 2-inch drain tile to the well or fill the ditches with loose broken stone. Keep the cellar pumped dry.

3d. Pave the cellar with hard-burned bricks, set on edge, laid in cement mortar, working from the four sides towards the cen-

ter, keeping the well open in order to pump out the water.

4th. On this foundation lay the cement concrete floor.

5th. When the floor is hard plug up the hole in the center with brick and quick-setting cement.

CONCRETE STEPS.

The following description of a method of laying concrete steps by R. B. Clement, a practical cement worker, which appeared in Municipal Engineering Magazine, will be of interest. For approaches to buildings, stairways, etc., the differences will be mainly in foundations and forms.

I first had the earth removed about 20 inches, and filled the excavation to the original surface of the ground with small field stones, well pounded down with a large sledge. I then put on a coat of 3 inches of coarse granite and cement and had it well rammed down. After it had set one day and night I began the steps. I put a wide $1\frac{1}{2}$-inch plank each side of the walk, 4 feet 10 inches apart, 4 feet for the length of steps and 5 inches at each end for a side railing, and then built in the side plank for each step, setting them 14 inches apart, though 16 inches would be better. I had these cross planks dressed and gouged out along the edge so that each step has a 2-inch half-round mold on it. I started the steps at the top, so that there would be no temptation to step on them while at work. The concrete was thoroughly well tamped into place. To form the side rails the outside plank and one 5 inches from it, cut to fit the steps, were used. The top of this railing, which was about 6 inches high, was neatly rounded off with the trowel. In joining on the rail to the steps plenty of water was kept on the steps at each end to make it stick. The surfaces of the steps were troweled off as soon as the planks were removed. All planks were removed after two days. Plenty of tallow was used on them to keep the cement from sticking. The foundation concrete may be one part of cement to five or six parts of gravel. The concrete for the railing and for the outside two inches of the steps should be quite rich in cement, say two parts of cement to one of coarse, clean, sharp sand. The steps should be thoroughly wet frequently for three or four days after the forms are removed to prevent checking and cracking while taking the final set. When the surfaces are thoroughly dry, thorough rubbing with coarse sandpaper and an old rasp will give a fine appearance to the surface. Anything built without a solid foundation that frost, rain or sun cannot touch will be work in vain.

CEMENT MORTAR, PHILADELPHIA.

Specifications for cement mortar for sidewalks, foundations,

masonry, etc., in Philadelphia, Pa., are as follows:

1. *Sand and Water.*—Sand shall be sharp, silicious, dry-screened, tide-washed bar sand—or approved flint bank sand, free from loam or other extraneous matter. The water must be fresh and free from dirt. When so directed by the Chief Engineer salt water may be required to prevent mortar from freezing when absolutely necessary to lay masonry in cold weather.

2. *Composition.*—Portland cement mortar shall be composed of one part of cement and three parts of sand. Natural cement mortar shall be composed of one part of cement and two parts of sand.

Mortar for pointing, grouting, bedding, coping stones and bridge seats, shall be composed of one part Portland cement and two parts sand. A greater proportion of cement shall be used when required.

3. *Mixing.*—The ingredients, properly proportioned by measurement, must be thoroughly mixed dry in a tight box of suitable dimensions, and the proper amount of clean water added afterwards. No greater quantity is to be prepared than is required for immediate use, and any that has "set" shall not be retempered or used in any way.

4. *Tensile Strength.*—Mortar taken from the mixing box, and molded into briquettes one square inch in cross-section, shall develop the following ultimate tensile strengths:

7 days (1 day in air, 6 days in water), 1 part of natural cement to 2 parts of sand	50 lbs.
28 days (1 day in air, 27 days in water) 1 part of natural cement to 2 parts of sand	125 lbs.
7 days (1 days in air, 6 days in water) 1 part of Portland cement to 3 parts of sand	125 lbs.
28 days (1 day in air, 27 days in water) 1 part of Portland cement to 3 parts of sand	175 lbs.

MORTAR AND CONCRETE, BUFFALO.

Specifications for cement mortar and concrete in Buffalo are as follows:

Sand and Mortar.—All sand used in the mortar must be clean, sharp, coarse, lake sand, free from loam or vegetable matter. The proportion of sand and cement for natural cement mortar will be two (2) of sand to one (1) of cement by measure. Sufficient water will be used to make a plastic mass. Pointing mortar will be mixed, one (1) of sand to one (1) of Portland cement. All cement mortars shall be used immediately after mixing, and any that has been mixed more than half an hour, or has commenced to set, shall be rejected and thrown away.

Concrete.—Concrete will consist of above described quality

of cement, clean, sharp, coarse, lake sand, and clean stone broken so that no dimension is larger than two (2) inches.

The cement and sand shall be mixed as required for mortar, and then thoroughly mixed by use of shovels with broken stone, in the proportion of one (1) cement, two (2) sand, five (5) of broken stone immediately before using. When put in place it will at once be leveled off, and tamped as directed by the engineer, but must not be touched afterwards.

When it is impossible to finish the concrete in one day, the surface and ends thereof to be left, and also the method of continuing such concrete to form good bond or union to be as the engineer may direct. No masonry to be built on the concrete until the engineer permits.

CEMENT MORTAR AND ITS USE IN SEWERS, MASONRY AND CONCRETE, INDIANAPOLIS.

Following are the specifications for mortar for all uses, prescribed by the City of Indianapolis, and the specifications for its use in laying sewer pipe, brick masonry, plastering and concrete for sewers and foundations:

Mortar.—1. A rectangular box shall be provided for mixing mortar, which, if required, shall be marked with cleats or otherwise to give quantities of cement and sand.

2. Mortar for brick and stone masonry and concrete shall consist of one part by measure of hydraulic cement, as specified, and two parts of clean, sharp sand, free from pebbles and vegetable matter. When properly measured into the box the sand and cement shall be thoroughly mixed dry until the mixture shows a uniform color. When wanted for use it must be wet with the smallest quantity of water possible, and be thoroughly mixed and tempered. The engineer may prescribe the number of times the mixture shall be turned over, dry and wet, if he considers if necessary. The mortar must be used immediately, and none remaining on hand so long as to have set shall be re-mixed and used.

3. For pointing and for wet ditches the proportions shall be one of cement to one of sand.

4. Neat cement may be required for pipe-laying in wet ditches.

5. Mortar for plastering catch-basins and pointing outside stone or brick masonry shall be mixed as above prescribed, using one part of Portland cement such as specified for this work, and one part clean, sharp sand, not of excessive coarseness, and free from pebbles and vegetable matter.

6. In any of the above mixtures the engineer may increase the proportions of cement for special reasons in particular

places. The proportions shall all be by measure in the mortar box prescribed. If other methods of measurement are permitted, the measurements shall be based on the measurement of the cement in the original package, and not after being removed therefrom.

Brick Sewer.—The bricks shall be clean and thoroughly saturated with clean water immediately before laying. Every brick shall be neatly and truly laid in line, in full joint of mortar at one operation, and in no case shall mortar be slushed or grouted in after the brick is laid, except when so directed by the Engineer. All brick must break joints with those in adjoining courses.

All joints below the springing line of the arch shall be neatly struck, and the joints of the arch shall be cleaned off to the face of the brick work after the centers have been removed. The joints between the courses of the inner ring shall not be more than one-quarter inch and the outer rings not more than one-half inch in thickness, and between the rings or shells there shall be one-half inch of mortar.

The centers of the intercepting sewer being struck, and all rubbish removed from the inside of the sewer, and the whole of the interior of the sewer being washed perfectly clean, it shall receive, while wet, a thin, and perfectly smooth plastering of Portland cement mortar, ¾ inch thick, laid on with plasterer's finishing trowel over the whole surface of the inside. This plastering must not be soiled or disturbed or trodden upon for at least forty-eight (48) hours after its application. Only intercepting sewers shall be plastered.

The outside surface of all catch-basins must be covered with cement mortar ½ inch thick. The inside surface shall be plastered to a thickness of ⅜ inch with mortar composed of one part of sand and one part of Portland cement.

The outside of all manholes shall be covered by a coat of cement mortar ½ inch thick.

Flush-tanks shall be built, plastered and tested as provided for catch-basins and of form and dimensions shown on plans.

Pipe Sewers.—Each pipe shall be laid in a firm bed and in perfect conformity with the lines and levels given. The bottom of the trench under each socket must be excavated so as to give the pipe a solid bearing for its whole length. The pipes must (if required) be fitted together and matched before lowering into the trench, so as to secure the truest possible line on the bottom of the inside pipes. They must be marked when in this position and laid in the trench as marked. No chipping of socket or spigot other than cutting off projections will be permitted, and any pipe injured in this process shall be rejected.

Unless otherwise specifically ordered, the pipe shall be laid from the lower end of the line upward. The engineer may require the pipe to be laid with level, line or straight-edge or in other manner that will produce the result above required, and may require that a light be set in the last manhole or lamphole and each pipe laid so that this light shall always be visible through the section of pipe under construction.

When laid in the trench as above specified, the joint shall be completely filled with mortar of one of sand and one of cement (see mortar specifications) in a manner fully satisfactory to the engineer. If he is not satisfied with the methods used by the contractor, he may prescribe the method and the materials to be used in filling the joints. Extra precautions shall be taken in wet ditches. Any excess of mortar on the inside of the pipe shall be cleaned out immediately after laying the joint.

Concrete.—Broken stone shall be sound, hard limestone, broken as nearly regular as practicable, which shall not measure more than 2½ inches in any direction, and which shall be screened through a revolving screen. It shall be free from dust, loam or dirt. When delivered on the line of the work, it shall be deposited on platforms made for the purpose, and the subgrade of pavement must be protected from injury by teams in hauling. All stone must be crushed or broken before being hauled upon the street, and under no circumstances will any stone be allowed to be hauled and deposited on the street and then broken.

Concrete for sewer work shall be composed of about 1½ measures of mortar, as specified, and four of broken stone, as above specified, or clean, screened gravel satisfactory to the engineer. The mortar and stone shall be so mixed in a box, or on a platform, according to the directions of the engineer, that every stone shall be completely covered with mortar. It shall be laid immediately and carefully placed in layers about six inches in thickness, and shall be settled in place by gentle ramming, only sufficient to flush the mortar to the surface. Before any layer is covered by another, its surface shall be scored so as to make a bond between the layers.

The concrete for foundations of pavements shall be made with Portland cement, sand and gravel. The proportions shall be 1 part of Portland cement and 5 parts of gravel. The mortar and gravel shall be so thoroughly mixed, as directed by the engineer, that every piece of gravel shall be completely coated with mortar. It shall then be deposited in place and rammed until the mortar is brought to the surface.

No walking or driving over the uncovered concrete foundation will be permitted, and it shall be allowed to set for eight

days, or such time as the engineer may direct, before any further work shall progress on the same. Concrete shall be planked at street and alley crossings to permit travel to cross it without injujry.

Concrete shall be sprinkled at night, when considered necessary by the engineer, and he may require it to be protected from the sun in hot weather, and from frost in cold weather, by covering with suitable material.

The thickness of concrete foundation shall be 6 inches, unless otherwise specifically stated.

The surface of the concrete shall be parallel to the finished surface of the street, and templets shall be used as directed by the engineer.

The engineer shall be notified before concrete laying is begun. and no work shall be done until he has examined and accepted the sub-grade.

If at any time, for violation of these specifications, any concrete shall, in the opinion of the engineer, prove entirely, or in any portion, inferior, it shall be removed by the contractor and replaced in a suitable manner.

CONCRETE SEWERS.

The city of Washington, D. C., constructs concrete sewers under two specifications for concrete.

The materials are pebbles from fine bank or river gravel thoroughly screened, free from earthy or other foreign matter and small enough to pass through a ring 1½ inches in diameter; clean, sharp sand free from mud, sewage, mica or other foreign matter equal to samples; fresh, clean water, free from earth, dirt or sewage; and Portland cement furnished by the city.

Mortar for concrete masonry, class A, is made of one part of Portland cement in perfect condition and two parts of loose, dry sand by volume; that for class B of one part cement and 2½ parts of sand; thoroughly mixed dry and then enough water added to make a stiff paste, being turned over and mixed with shovels not less than six times, if mixed by hand, before the water is added. Mortar must be used within an hour after the water is added to it.

Concrete masonry of each class is made of the respective mortars and pebbles, the amount of mortar to be 25 per cent. in excess of the volume of voids in the pebbles.

The pebbles are drenched with water and added to the mortar in the proportions determined for the material in use, and the mass is thoroughly turned over not less than four times and mixed on a water-tight platform until every particle of the

pebbles is completely enveloped with mortar, the work being done as expeditiously as possible.

Concrete is lowered to place in buckets, carefully deposited so as to keep its even mixture and free from foreign matter, spread in horizontal layers not exceeding 5 inches in thickness, and at once thoroughly compacted by ramming.

Strong molds, forms and centers are used, made to fit the curves and shape of all the work and kept scraped clean from cement and dirt.

The back of every arch is thoroughly cleaned of dirt or loose or projecting mortar and smoothly plastered from the springing line to the crown with a coat of mortar, ⅜ in. thick. The arches are allowed to set at least 24 hours before back-filling, walking or working on them or any weights are applied.

The back-filling is brought up evenly on both sides of the sewer, so that no unbalanced pressure is brought upon the masonry. It is spread in horizontal layers not exceeding 6 inches in depth and thoroughly rammed.

Water must be kept out of the trench until the cement has set beyond the chance of injury.

The accompanying illustration shows the method of manu-

MAKING BLOCKS FOR COLDWATER, MICH., SEWER.

facture and treatment of the concrete blocks of which the upper arch of a sewer in Coldwater, Mich., was constructed, the invert being laid as a monolith. The invert is 8 inches thick and the blocks were 8 inches deep by 24 inches long, and 5¾ inches chord on the intrados, the sewer being 3.5 feet in diameter. Concrete was made of 1 part Portland cement to 6 parts of gravel, the proportion of water being particularly important in molding the blocks, too much water causing the concrete to stick to the molds and too little to leave the block dry and crumbly before the cement had set. Appearance of water on the surface after ramming indicated proper consistency. No form was used in laying the invert, the shape being roughly made with shovels and rammers, a float or board held along the inside aiding in making the inside shoulder stand up square. A semi-circular templet drawn along the surface gave one a half-inch larger than the finished invert, a heavy coat of mortar, made one part of cement to two parts of sand being troweled on while the concrete was still green and brought to true surface by another templet.

CURING OF CEMENT BLOCKS.

The following specification for curing cement blocks is abstracted from a paper by James Wimmer on this subject:

One of the most important features of block manufacture is the curing process. A block must cure uniformly. The primal requisite in proper curing is water and plenty of it. No stated time can be given for beginning sprinkling, as all depends on the atmospheric conditions. Some days it can be begun in three hours and at other times five to eight hours must elapse before the water can be safely applied. The moment the outer surface begins to turn light the block needs water, and it should be supplied as often as this light color is noticed. Too much water cannot be applied, provided it is sprinkled on. This watch of the blocks and frequent application of water should continue for at least forty-eight hours, or until the blocks are removed from the pallets and piled in the storage house. Lath should be placed between the tiers of blocks and the blocks should be sprinkled frequently for five to eight days. A hose and spray will reach the blocks if piled as specified. This watering should be one responsible man's business. It is very important.

FILLERS FOR BRICK PAVEMENTS.

Portland cement is now very generally used as a filler for

the joints in brick and other block pavements. Perhaps the Murphy grout was the first application to this purpose, this grout being a proprietary mixture of Portland cement and finely ground slag high in silicate of alumina, with water and sand in proper proportions substantially the same as used with Portland cement.

The Indianapolis specifications for cement filler are as follows:

The joints shall then be filled as nearly as possible from bottom to top with a paving cement or grout as specified in the bid and contract, and according to a formula for composition and consistency of same approved by the Board of Public Works and the Engineer. Sand may be used as a filler in alleys when specifically stated in specifications, to be applied as directed by the Engineer.

When grout is used it must be equal or superior to a grout composed of one part of Portland cement by measure and 1½ parts of fine sand, which will pass through a 3-16-inch mesh. It shall be of such consistency as to run readily into the joints and shall be swept in rapidly. The pavement shall be gone over a sufficient number of times to fill every joint. When the foundation is of broken stone, the Engineer may require the grout to be put on in two coats, the first coat to be of such proportions as he may direct.

Opinions vary regarding the method of applying the grout, some first applying a coat richer in cement than above specified and following with one similar to that specified. Experiment has shown that, with a broken stone foundation, likely to absorb a coat put on too thin, the first application may be with advantage of a mixture of one cement to three sand, well mixed with sufficient water to make it run freely, and applied in small quantities with sufficient rapidity to get it into the joints without too much separation of the sand and cement. This serves to fill the lower part of the joints and the top of the sand cushion. When it has stood a short time, it can be followed up with the specified mixture applied often enough to fill the joints completely. Some cement is saved in this way, as the joints are filled without at the same time filling a good share of the foundation.

LINING FOR DITCHES AND AQUEDUCTS.

Portland cement has been used in California for lining irri-

gation ditches to make them more nearly water-tight. The following is a description of the process:

In preparing for the cementing work, sand is first hauled from nearby river beds, or washes as they are called, and dumped along the line of the ditch where it will be required for mortar. The laborers are boarded in temporary tent camps, in order to be near the work as it advances. With the exception of a foreman and two trowelers day laborers are employed. A mortar-bed on wheels is drawn by a horse along the edge of the canal, keeping pace with the plasterers. Shovelers in advance of the plasterers clean out and even off the surface, and a man with a hose follows and sprinkles the surface so that it is thoroughly wet before plastering.

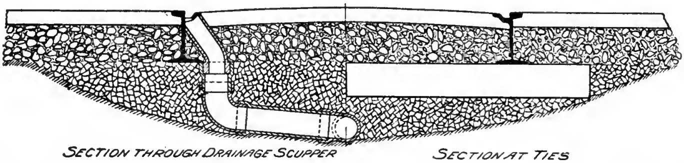
The sand is not screened, but is selected to contain a good proportion of coarse as well as fine grains and to be clean. It is mixed on the portable bed in the proportion of one of cement to four of sand. It is mixed with hose first dry and then wet. The mortar is then slid down the chute onto a bed from which the shovelers spread it along the bottom and sides as fast as the trowelers can spread it to a surface. This coat of plaster is generally made from ¼ to ½-inch thick on canal work, but on this work the coat was from ⅛ to ¼-inch thick. Within fifteen minutes after water has been added to the mortar the last of it is plastered on the ditch. The plastered surface is sometimes washed over with a wash of pure cement and water applied with a brush to make it more impervious to water. After standing a couple of days, water is allowed in the finished section, but is kept stagnant by means of temporary dirt dams. From these reservoirs temporary lines of ¾-inch iron pipes carry water to the mortar bed as it keeps pace with the construction.

STREET RAILWAY FOUNDATIONS.

For street railway work Chicago has the following form of concrete construction under ties and of making junctions of track with various kinds of pavements:

Concrete.—The depth should be determined by the engineer in charge, but will vary from four to twelve inches, according to the exigencies of the case, or solidity of the foundations. The concrete width is usually one foot outside the ties at each side, or nine feet in width for a seven-foot tie. The constituent parts of the concrete are one part of cement, two parts of sand —sharp—and four or five parts of broken stone or gravel, small enough to pass through a two-inch ring. Mix the sand and cement dry, and turn over four times before using water. Wet the stone before adding it to the sand and cement and mix thor-

oughly on a board platform with tight joints. After spreading concrete, ram it thoroughly, until water appears on the top, keeping it uniform and smooth. Spread one inch of coarse sand or gravel over the concrete for tie bed. The space between



LIGHT CONCRETE CONSTRUCTION, HARTFORD, CONN., STREET RAILWAY.

the ties should be filled with concrete, broken stone, gravel or sand, as the engineer decides, thoroughly tamped or rolled and brought to an even surface, ready for the paving, which should be impervious to water.

SOLID CONCRETE CONSTRUCTION, BUFFALO STREET RAILWAY. GROUTING BRICK PAVEMENT.

Paving.—In cities the paving may be Belgian block, brick concrete or asphalt, and in the suburbs ordinary earth is used, if ballast of broken stone, gravel, screenings or cinders is too expensive.

Much trouble is occasioned by the loosening of the pavement along the rails and over the ties. It should be laid close and

compact, with the interstices filled with paving pitch or grout, so as to insure its being impervious. Where macadam, concrete or asphalt is used, there should be next the rail a toothing of block paving of stone or brick, to prevent disturbances of the pavement by the rail vibration.

Fine cement is used on each side of the rail web to allow the paving to fit against the lip of the rail. The usual depth of Belgian blocks is six inches, and they rest on a bed of sand one inch deep. There should be no projection to prevent the pavement from fitting close to the rail.

Concrete is much preferred abroad for foundation to broken stone; in fact, the latter is never allowed to be used

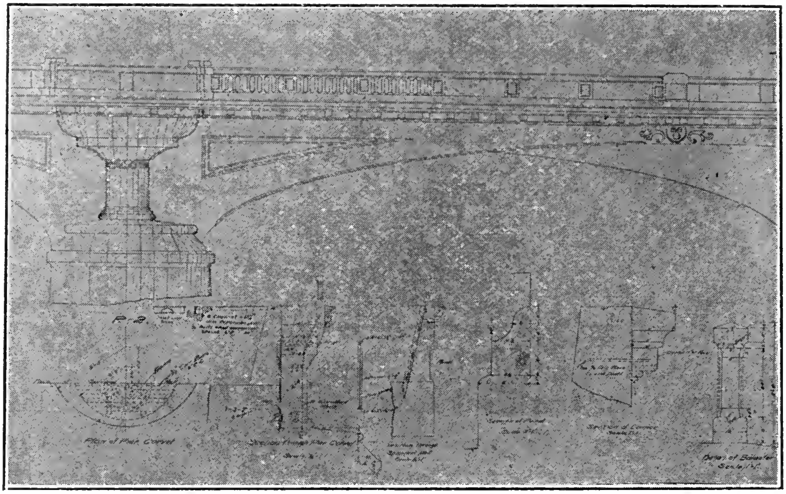
With brick paving, the concrete should be brought to within one inch of the bottom of the bricks, then one inch of sand, spread very evenly, and lastly the bricks, laid very true, no brick the least bit higher than the adjoining ones.

In Cincinnati, O., a concrete stringer 12 to 15 inches deep, 16 inches wide at bottom and 18 inches wide at top is laid, using Portland cement and limestone. This stringer extends 9 inches below the bottom of the 9-inch rail and is continued to surround the lower flange of the rail and from 3 to 6 inches up the web according to whether the pavement is brick or asphalt. The space about the rail up to the head is filled with Portland cement so that the rail is completely enclosed excepting the upper wearing surface. Cross-ties of wood are used at intervals of 10 feet and steel tie bars at intervals of 5 feet. Denver uses similar construction, with cross-ties and tie-rods at intervals of 6 feet, concrete on one portion being made of Portland cement 1 part and gravel and sand 5 parts, and on another portion of natural hydraulic cement 1 part and gravel and sand 3 parts. The rail rests on top of the concrete beam. Detroit uses a concrete beam extending 8 inches below the rail, which rests on it, 12 inches wide at top and 8 inches wide at bottom. Wooden or steel cross-ties are used. Several cities use constructions differing only in minor details from those named. Scranton, Pa., improves upon it by using pieces of old rails for cross-ties. Concrete is made of 1 part Portland cement, 3 parts sand and 5 parts broken stone.

METHOD OF CONCRETING. MONIER ARCH BRIDGE, PHILADELPHIA.

After the entire mason work of the old stone bridge was torn down to low-water mark, substantial wooden cofferdams

were built from rock bottom up to the elevation of the springing line of the new bridge around the center pier and both abutments, properly anchored to the ground, braced, and sheet piled at the inside and outside with clay puddle between, to make a solid and water-tight caisson for the whole concreting, and at the same time to serve as support for the centering and casing of the arches; 12x12-in. yellow pine timbers were used for the frame work of the cofferdams and for the adjustable trusses of the centerings, and 3-in. planks, also of yellow pine, for the covering and sheet-piling. To prevent any



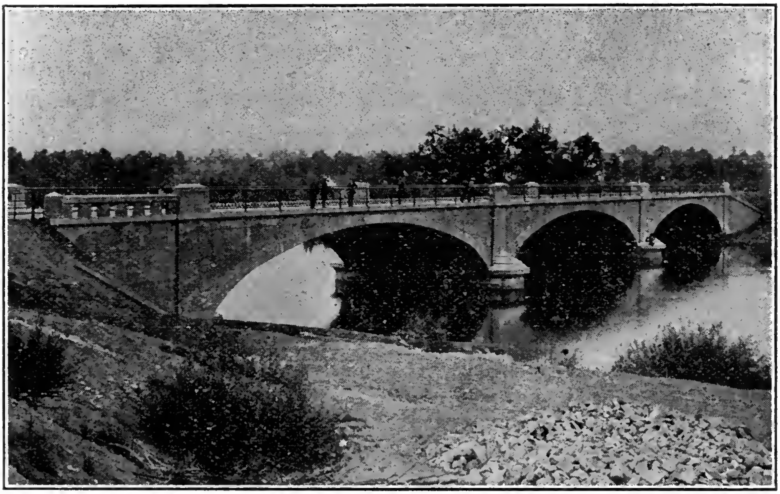
ELEVATION OF MELAN ARCH, SOUTH BEND, IND., AND SECTIONS OF RAILING AND ORNAMENTAL WORKS.

adhesion of the concrete to the wood-work, the corresponding surfaces were planed, oiled and sanded. In order to discharge the surplus water at any rate accumulated at the bottom of the concrete after its setting, small holes about 3/8 of an inch in diameter were made in the planks when and wherever required.

As soon as the coffer-dams were completed and all water pumped out, the old mason work below low-water mark was excavated to said bottom, the top surface then first thoroughly cleaned, wetted and slushed with neat Portland cement; and then the first layer of concrete placed in a thickness not exceeding 12 inches, so as to secure a thorough level base for all subsequent layers, 9 inches thick, up to the springing line of the arches, laid in uninterrupted continua-

tion, until one layer was placed always through on either part of the bridge.

Then the arches were concreted in the same manner in subsequent equal layers of concrete, each one closing 9 inches thick at the crown. The concrete was applied from a movable platform by regular tight mortar barrows, in equal portions central to the arches, beginning at the haunches and continuing towards the crown of the arches at the same time, so as to secure a uniform setting of the concrete. After the first



MELAN ARCH WITH CONCRETE FACE, MISHAWAKA, IND.

setting of each layer (requiring from 1½ to 2 hours after its bedding), a subsequent layer was placed, and so on. To obtain a proper binding between the layers, during high temperature, the top surface of each layer was kept damp; and during the interruption of the work at night-time and on Sundays the top surface was covered with damped canvas, and during heavy rain-storms with planks.

Wire nets, a la system "Monier," were placed between each layer, 12 inches apart square, of ⅛-inch galvanized iron wires, anchored by upright rods to the haunches and abutments.

SPECIFICATIONS FOR MELAN ARCH BRIDGE AT TOPEKA, KANSAS.

Plans.—The work shall be constructed complete in accordance with the general plans, sections and diagrams herewith submitted, and these specifications. The specifications and drawings are intended to describe and provide for the com-

plete work. They are intended to be co-operative, and what is called for by either is as binding as if called for by both. The work herein described is to be completed in every detail, notwitstanding that every item necessarily involved is not particularly mentioned. The contract price shall be based upon these specifications and drawings, which are hereby signed and made a part of the contract.

Conditions of Calculation.—

Modulus of elasticity of concrete..............	1,400,000 lbs.
Modulus of elasticity of steel..................	28,000,000 lbs.
Maximum stress per square inch on steel.......	10,000 lbs.
Maximum compression per square inch on concrete	500 lbs.
Maximum shear per square inch on concrete....	100 lbs.
Maximum tension per square inch on concrete..	50 lbs.

The above are to be exclusive of temperature stresses. The steel ribs under a stress not exceeding their elastic limit must be capable of taking the entire bending moment of the arch, without aid from the concrete, and have a flange area of not less than 1-150 part of the section of concrete at crown.

Discrepancies.—In the event of any discrepancies between the drawings and the figures written on them, the figures are to be taken as correct, and in cases of any discrepancy between the drawings and the specifications, the specifications are to be adhered to.

Foundations.—All foundations shall be shown on plans, and conform to the dimensions marked thereon. Foundations on rock shall be prepared by removing all sand, mud or other soft material, and by excavating the bed rock in such manner as may be described or shown on drawings. Foundations on hardpan, gravel and clay, cemented sand, or other material intended to carry the load without piles, shall be excavated to the depths shown on plans.

Foundations on piles, when not otherwise described, shall be inclosed in a permanent coffer-dam or crib, and be excavated to the depths shown on plans, and the piles shall be driven after the excavations are made. The spaces between the piles shall be filled with concrete, and in case it is found necessary to lay the concrete under water proper appliances must be used to insure its being deposited with as little injury as possible. The piles shall be oak, yellow pine or other wood that will stand the blow of the hammer, straight, sound and cut from live timber, trimmed close, cut off square at the butt, and have all bark taken off. The piles shall not be less than 12 inches nor more than 16 inches in diameter at the

large end, nor less than 10 inches in diameter at the small end for piles having a length of 30 feet and under. For greater lengths the diameter of small end may be reduced 1 inch for each 10 feet of additional length down to a minimum of 7 inches. The piles shall not be loaded with a weight greater than given by the following formula: $L = 2wh \div (s + 1)$, in which L = safe load in pounds; w = weight of hammer in pounds, h = fall of hammer in feet, s = last penetration in inches. The number and arrangement of the piles for each foundation shall be shown on plans, and they shall be sawed off at the elevation shown.

Cement.—The cement shall be a true Portland cement, made by calcining a proper mixture of calcareous and clayey earths; and if required, the contractor shall furnish a certified statement of the chemical composition of the cement, and the raw materials from which it is manufactured. The fineness of the cement shall be such that at least 99 per cent. will pass through a sieve of 50 meshes per lineal inch, at least 90 per cent. will pass through a sieve of 100 meshes per lineal inch, and at least 70 per cent. will pass through a sieve of 200 meshes per lineal inch.

Samples for testing may be taken from each and every barrel delivered, unless otherwise specified. Tensile tests will be made on specimens prepared and maintained until tested at a temperature of not less than 60 degrees F. Each specimen will have an area of 1 square inch at the breaking section, and after being allowed to harden in moist air for 24 hours, will be immersed and maintained under the water until tested. The sand used in preparing the test specimens shall be clean, sharp, crushed quartz, retained on a sieve of 30 meshes per lineal inch. No more than 23 to 27 per cent. of water shall be used in preparing the test speciments of neat cement, and in the case of test specimens of 1 cement and 3 sand, no more than 11 or 12 per cent. of water by weight shall be used.

Specimens prepared from neat cement shall after seven days develop a tensile strength of not less than 450 lbs. per square inch. Specimens prepared from a mixture of 1 part cement and 3 parts sand, parts by weight, shall after seven days develop a tensile strength of not less than 160 lbs. per square inch, and not less than 220 lbs. per square inch after 28 days. Specimens prepared from a mixture of 1 part cement and 3 parts sand, parts by weight, and immersed after 24 hours in water maintained at 176 degrees F., shall not swell nor crack, and shall, after seven days, develop a tensile strength of not less than 160 lbs. per square inch. Cement

mixed neat with about 27 per cent. of water to form a stiff paste, shall after 30 minutes be appreciably indented by the end of a wire 1-12 inch in diameter loaded to weigh 1/4 lb. Cement made into thin cakes on glass plates, shall not crack, scale or warp under the following treatment: Three pats will be made and allowed to harden in moist air at from 60 degrees to 70 degrees F.; one of these will be subjected to water vapor at 176 degrees F. for three hours, after which it shall be immersed in hot water for 48 hours; another shall be placed in water at from 60 degrees to 70 degrees F., and the third shall be left in moist air. All cement shall be kept housed and dry until wanted in the work.

Portland Cement Concrete.—The concrete shall be composed of clean, hard broken stone, or gravel, with irregular surface; clean, sharp sand, and cement, mixed in the proportions hereafter specified. Whenever the amount of work to be done is sufficient to justify it, approved mixing machines shall be used. The ingredients shall be placed in the machine in a dry state, and in the volumes specified, and be thoroughly mixed, after which clean water shall be added and the mixing continued until the wet mixture is thorough and the mass uniform. No more water shall be used than the concrete will bear without quaking in ramming. The mixing must be done as rapidly as possible and the batch deposited in the work without delay.

If the mixing is done by hand, the cement and sand shall first be thoroughly mixed dry in the proportions specified. The stone previously drenched with water shall then be deposited on this mixture. Clean water shall be added and the mass be thoroughly mixed and turned over until each stone is covered with mortar, and the batch shall be deposited without delay, and be thoroughly rammed until all voids are filled. The grades of concrete to be used are as follows: For the arches between skewbacks—1 part Portland cement, 2 parts sand and 4 parts broken stone, or gravel, that will pass through a 1¼-inch ring; for the foundations, abutments, piers and spandrels—1 part Portland cement, 4 parts sand and 8 parts broken stone or gravel, that will pass through a 2-inch ring.

Concrete Facing.—If concrete facing is used it shall be composed of 1 part Portland cement and 2½ parts sand, and shall have a thickness of at least 1 inch on all arch soffits, arch faces, abutments, piers, spandrels or other exposed surfaces. There must be no definite plane or surface of demarkation between the facing and the concrete backing. The facing and backing must be deposited in the same layer, and

be well rammed in place at the same time. If the arch faces, quoins or other exposed surfaces are marked to represent masonry, such division marks shall be made by triangular strips 2 inches wide and 1 inch deep fastened to the casing in perfectly straight and parallel lines, and all projecting corners will be beveled to correspond.

Plastering.—No plastering will be allowed on the exposed faces of the work, but the inside faces of the spandrel walls covered by the fill may be plastered with mortar having the same composition as specified for facing.

Stone Facing.—If stone facing is used the ring stones, cornices and faces of spandrels, piers and abutments shall be of an approved quality of stone. The stone must be of a compact texture, free from loose seams, flaws, discolorations or imperfections of any kind, and of such a character as will stand the action of the weather. The spandrel walls will be backed with concrete, or rubble masonry, to the thickness required. The stone facing shall in all cases be securely bonded or clamped to the backing. All stone shall be rock-faced with the exception of cornices and string courses, which shall be sawed or bush-hammered. The ring stones shall be dressed to true radial lines, and laid in Portland cement mortar, with ¼-inch joints. All other stones shall be dressed to true beds and vertical joints. No joints shall exceed ½ inch in thickness, and shall be laid to break joints at least 9 inches with the course below. All joints shall be cleaned, wet and neatly pointed. The faces of the walls shall be laid in true line, and to the dimensions given on plans, and the corners shall have a chisel draft 1 inch wide carried up to the springing lines of the arch, or string course. All cornices, moldings, capitals, keystones, brackets, etc., shall be built into the work in the proper positions, etc., and shall be of the forms and dimensions shown on plans.

Brick Facing with Concrete Trimmings.—The arch rings, cornices, string courses and quoins, shall be concrete-faced as described above, the arch rings and quoins being marked and leveled to represent masonry. The piers, abutments and spandrels shall be faced with vitrified brick as shown on plans. The brick facing shall be plain below the springing lines of the arches, and rock-faced above these lines. All rock-faced brick shall be chipped by hand from true pitch lines. All brick facing shall be bonded as shown on plans, at least one-fifth of the face of the wall being headers. The brick must be of the best quality of hard-burned paving brick, and must stand all tests as to durability and fitness required by the engineer in charge. The bricks must be regular in

shape and practically uniform in size and color. They shall be free from lime and other impurities; shall be free from checks or fire cracks, and as nearly uniform in every respect as possible; shall be burned so as to secure the maximum hardness; so annealed as to reach the ultimate degree of toughness; and be thoroughly vitrified so as to make a homogeneous mass. The backing shall be carried up simultaneously with the face work, and be thoroughly bonded with it.

Artificial Stone.—All keystones, brackets, consoles, dentils, pedestals, hand-railing posts and panels and other ornamental work when used, also curbs and gutters, shall be of the design shown on plans, and be molded in suitable molds. The mortar for at least 1 inch thick shall consists of 1 part Portland cement and 2½ parts sand, and when the size of the molding will admit, the interior may be composed of concrete of the same composition as specified for the arches. When pedestals, posts or panels carry lampposts a 4-inch wrought-iron pipe shall be built into the concrete from top to bottom, and at bottom shall be connected with a 3-inch pipe extending under the sidewalk, and connected with a gaspipe or electric wire conduit. The pipes shall have no sharp bends, all changes in direction being made by gentle curves.

Sprinkling.—During warm and dry weather all newly built concrete shall be well sprinkled with water for several days, or until it is well set.

Mixtures.—The volumes of cement, sand and broken stone in all mixtures of mortar or concrete used in the work shall be measured loose.

Connections.—In connecting concrete already set with new concrete the surface shall be cleaned and roughened, and mopped with a mortar composed of 1 part Portland cement and 1 part sand, to cement the parts together.

Arches.—The concrete for the arches shall be started simultaneously from both ends of the arch, and be built in longitudinal sections wide enough to inclose at least two steel ribs, and of sufficient width to constitute a day's work. The concrete shall be deposited in layers, each layer being well rammed in place before the previously deposited layer has had time to set partially. The work shall proceed continuously day and night, if necessary, to complete each longitudinal section. These sections while being built shall be held in place by substantial timber forms, normal to the centering and parallel to each other, and these forms shall be removed when the section has set sufficiently to admit of it. The sections shall be

connected as specified above, and also by steel clamps or rib connections built into the concrete.

Drainage.—Provision for drainage shall be made at each pier as follows: A wrought-iron pipe of sufficient diameter shall be built into the concrete, extending from the center of each space over pier to the soffit. The surface of concrete over piers shall be so formed that any water that may seep through fill above will be drained to the pipes. The line of drainage will be covered with a layer of broken stones, and the top of pipes will be provided with screens to prevent clogging.

Steel Ribs.—Steel ribs shall be imbedded in the concrete of the arch. They shall be spaced at equal distances apart, and be of the number shown on plans. Each rib shall consist of two flat bars of the sizes marked on plans. The bars shall be in lengths of about 30 feet, thoroughly spliced together, and extending into the abutments as shown. Through the center of each bar shall be driven a line of rivets spaced 8 inches, c. to c., with heads projecting about 7/8 inch from each face of bar, except through splice plates, where ordinary heads will be used. The bars shall be in pairs with their centers placed 2 inches within the inner and outer lines of the arch respectively as shown. All steel must be free from paint and oil, and all scale and rust must be removed before imbedding in the concrete.

The tensile strength, limit of elasticity and ductility shall be determined from a standard test piece cut from the finished material and turned or planed parallel. The area of cross-section shall not be less than 1/2 square inch. The elongation shall be measured after breaking on an original length of 8 inches. Each melt shall be tested for tension and bending. Test pieces from finished material prepared as above described shall have an ultimate strength of from 60,000 to 68,000 lbs. per square inch; an elastic limit of not less than one-half of the ultimate, shall elongate not less than 20 per cent. in 8 inches, and show a reduction of area at point of fracture of not less than 40 per cent. It must bend cold 180 degrees around a curve whose diameter is equal to the thickness of piece tested without crack or flaw on convex side of bend. In tension tests the fracture must be entirely silky.

Rivet Steel.—Test pieces from finished material, prepared as above described, shall have an ultimate strength of from 54,000 to 62,000 lbs. per square inch, an elastic limit of not less than one-half of the ultimate strength, shall elongate not less than 20 per cent. in 8 inches, and show a reduction at point of fracture of not less than 50 per cent. It must bend cold 180 degrees and close down on itself without fracture on convex side of bend. In tension tests the fracture must be entirely silky.

Inspection.—The contractor shall furnish a testing machine of the proper capacity and shall prepare and test without charge such specimens of steel as may be required to prove that it comes up to the requirements mentioned above.

Workmanship.—The rivet holes for splice plates of abutting members shall be so accurately spaced that when the members are brought into position the holes shall be truly opposite before the rivets are driven. When members are connected by bolts the holes must be reamed parallel and the bolts turned to a driving fit. Rivets must completely fill the holes, have full heads concentric with the rivets, and be machine driven when practicable.

Centering.—The contractor shall build an unyielding false work or centering. The lagging shall be dressed to a uniform size so that when laid it shall present a smooth surface, and this surface shall conform to the lines shown on the drawings. The center shall not be struck until at least 28 days after the completion of the arch. Great care shall be used in lowering the centers so as not to throw undue strains upon the arches. The tendency of the centers to rise at the crown as they are loaded at the haunches must be provided for in the design, or, if not, the centers must be temporarily loaded at the crown, and the load be so regulated as to prevent distortion of the arch as the work progresses.

Casing.—When concrete facing is used all piers, abutments and spandrel walls shall be built in timber forms. These forms shall be substantial and unyielding, of the proper dimensions for the work intended, and all parts in contact with exposed faces of concrete shall be finished to a perfectly smooth surface, by plastering or other means, so that no mark or imperfection shall be left on the work.

Waterproofing.—After the completion of the arches and spandrels, and before any fill is put in, the top surface of arches, piers and abutments and the lower 6 inches of the inner surface of the spandrel walls shall be covered with a suitable waterproof material, so as to exclude water effectually.

Fill.—The space between spandrel walls shall be filled with sand, earth, cinders or other suitable material, and be thoroughly compacted by ramming, steam road roller, saturating with water or other effective means, and be finished to the proper grade to receive the curbing and pavement.

Granitoid Sidewalks.—The spaces over which the sidewalks are to be laid shall first be covered with 6 inches of cinders well compacted. On this shall be laid 4 inches of concrete, consisting of 1 part Portland cement, 3 parts sand and 6 parts broken stone or gravel—small size—well rammed. The flag

divisions shall then be marked off to the desired size. On the surface of the concrete shall then be laid a wearing surface 1 inch thick, composed of 2 parts Portland cement and 3 parts broken granite or other acceptable stone, in size from $\frac{3}{8}$ inch downward. It shall be well rammed and troweled to a perfectly even surface and rolled with a toothed roller. This wearing surface must be spread on the concrete while the latter is still soft and adhesive, and neat connections must be made with cornices and curbs.

Roadway Pavement.—The pavement shall be of the kind shown on plans or mentioned in proposal, and shall be built according to the specifications adopted in the locality where used, unless otherwise mentioned.

Retaining Stone.—There shall be set at each end of roadway pavement a line of stones of approved quality, 4 inches in thickness and 18 inches deep, with top surface conforming to contour of pavement.

Balustrades and Hand-Railings.—The balustrades shall be of the material and of the form and dimensions shown on plans, and shall be brought to true alignment and be firmly fastened to the outside of each sidewalk in the position shown. If an iron hand-railing is used, it shall receive two coats of approved paint after erection.

Erection.—The contractor shall employ suitable labor for every kind of work, and all stone work shall be laid by competent masons. The contractor will furnish all staging, piling, cribbing, centering, casing and material of every description required for the erection of the work; also all plant, including dredges, engines, pumps, derricks, barges, mixing machines, pile drivers, conveyors or other appliances necessary for carrying on all parts of the work. The contractor shall assume all risks for loss or damage incurred by ice, floods, fire or other causes during the construction of the work, and shall sufficiently watch and light the work at night during construction.

Cleaning Up.—Upon completion of work, and before final acceptance thereof, the contractor shall remove all temporary work from the river and all rubbish from the streets.

Maintaining Public Travel.—If public travel is to be maintained during the construction of the new bridge by the removal of old bridge, construction of temporary bridge or otherwise, special mention of the same shall be made.

Removal of Old Bridge.—If the site of the proposed structure is occupied by an old bridge, the same shall be removed by the contractor. The iron work shall be piled on the bank and the timber and stone shall become the property of the contractor.

Work Embraced by Contract.—The work embraced by con-

tract will be for the structure complete from out to out of abutments or retaining walls, as per plans and specifications, and will embrace fill, pavement, sidewalks and balustrades complete for this length.

Approaches.—The approaches will commence where the work above mentioned ends, and if all or any part of them is included in contract the same shall be specially mentioned.

Changes.—The committee in charge shall have power to direct changes which they may consider necessary or advisable in any part of the work, and such changes shall not in any way violate the contract, but the value of such changes shall be added to or deducted from the contract price, and any dispute as to their value shall be settled by arbitration in the usual way.

Inspection.—All material furnished by the contractor shall be subjected to the inspection and approval of the committee in charge.

Lamp Posts, Trolley Poles and Name Plates.—If used these shall be shown on plans, or be specially mentioned.

Interpretation of Plans and Specifications.—The decision of the committee in charge or their engineer shall control as to the interpretations of drawings and specifications during the execution of the work thereunder, but this shall not deprive the contractor of his rights to redress, after the completion of the work, for any improper orders or decisions.

Estimates.—Approximate estimates of work done and material delivered shall be made on or about the last day of every month, and a valuation of the same in proportion to contract prices for the completed work will be made by the committee in charge or their engineer, which sum shall be paid to the contractor in cash, on or about the 10th day of the following month, less a deduction of 10 per cent. upon said valation, which shall be retained until the final completion of the work.

Final Payment.—Upon the final completion of the work the contractor shall be promptly paid any balance of the contract price which shall then remain due and unpaid.

One significant change in specifications since the above were written in 1900 is seen in the requirement by Marion County, Indiana, for similar bridges designed in 1904, that concrete shall be mixed by machine and that hand mixing will not be permitted. This change is very general, the improvement in mixing machines making their use imperative on work of any great extent, on account of both thoroughness and economy.

SPECIFICATIONS FOR REINFORCED CONCRETE ARCHES IN INDIANAPOLIS, IND.

The following provisions are from the specifications for reinforced concrete arches in Indianapolis, Ind., in force in 1904 and 1905. They differ from those given in previous editions of this book only in the way of simplification and in such items as the requirement of machine mixing, which show the developments in methods of operation.

1. *Plans.*—The work shall be constructed complete in accordance with the general plans, sections and diagrams herewith submitted and these specifications.

The specifications and drawings are intended to describe and provide for the complete work. They are intended to be co-operative, and what is called for by either is as binding as if called for by both. The work herein described is to be completed in every detail, notwithstanding that every item necessarily involved is not particularly mentioned. The contract price shall be based upon the specifications and drawings, which are hereby signed and made a part of the contract.

Conditions of Calculation.—

Modulus of elasticity of concrete	1,400,000 lbs.
Modulus of elasticity of steel	28,000,000 lbs.
Maximum stress per square inch of steel	10,000 lbs.
Maximum compression per square inch on concrete	500 lbs.
Maximum shear per square inch on concrete	100 lbs.
Maximum tension per square inch on concrete	50 lbs.

(The above to be exclusive of temperature stresses.)

The steel ribs under a stress not exceeding their elastic limit must be capable of taking the entire bending moment of the arch without aid from the concrete, and have a flange area of not less than 1-150 part of the section of concrete at crown.

2. *Discrepancies.*—In the event of any discrepancies between the drawings and the figures written on them, the figures are to be taken as correct, and in case of any discrepancy between the drawings and the specifications, the specifications are to be adhered to.

3. *Foundations.*—All foundations are shown on plans and must conform to dimensions marked thereon. Foundations on piles when not otherwise described, shall be enclosed in a permanent coffer-dam or crib, and be excavated to the depths shown on plans, and the piles shall be driven after the excavations are made. The spaces between the piles shall be filled with concrete, and in case it is found necessary to lay the concrete under water, proper appliances must be used to insure

its being deposited with as little varying as possible. The piles shall be oak, yellow pine, or other wood that will stand the blow of the hammer, straight, sound, and cut from live timber, trimmed close, cut off square at the butt and have all bark taken off. The piles shall not be less than 12 nor more than 16 inches in diameter at the large end, nor less than 10 inches in diameter at the small end. The number and arrangement of the piles for each foundation shall be shown on plans and they shall be sawed off at the elevation shown.

4. For cement specifications, see chapter on Specifications for Cement.

5. *Concrete.*—The concrete shall be composed of clean, hard broken stone or gravel, with irregular surface, clean, sharp sand and Portland cement, mixed in the proportions hereinafter specified. Approved mixing machines shall be used. The ingredients shall be placed in the machine in a dry state and in the volumes specified, and be thoroughly mixed, after which clean water shall be added and the mixing continued until the wet mixture is thorough and the mass uniform. No more water shall be used than the concrete will bear without quaking in ramming. The mixing must be done as rapidly as possibe and the batch deposited on the work without delay.

The grades of concrete to be used are as follows: For the arches between skewbacks: 1 part Portland cement, 2 parts sand and 4 parts gravel that will pass through a 1¼ inch ring; for the foundation, abutments, piles and spandrels: 1 part Portland cement, 3 parts sand and 6 parts broken stone or gravel that will pass through a 2-inch ring.

6. *Stone Facing.*—The ring stones, cornices and faces of spandrels, piers and abutments shall be of the best Bedford stone. The stone must be of a compact texture, free from loose seams, flaws, discolorations, or imperfections of any kind, and of such character as will stand the action of the weather. The spandrel walls will be backed with concrete or rubble masonry to the thickness required. The stone facing shall in all cases be securely bonded or clamped to the backing. All stones shall be rock-faced with the exception of cornices, ring stones, railing and string courses, which shall be sawed or planed. The ring stones shall be dressed to true radial lines and laid in Portland cement mortar with ¼-inch joints. All other stones to be dressed to true beds and vertical joints. No joints shall exceed one-half of an inch in thickness and shall be laid to break joints at least 9 inches with the course below. All joints shall be cleaned, wet and neatly pointed. The faces of the walls shall be laid on true lines and to the dimensions given on plan, and the corners shall have a chisel draft one inch wide carried up to the springing line of the arch, or string course.

All cornices, capitals, moldings, keystones, brackets, etc., shall be built into the work in proper position and shall be of the forms and dimensions shown on plan and according to detail plans to be furnished.

7. *Sprinkling.*—During dry and warm weather all newly built concrete shall be kept well sprinkled with water for several days, or until it is well set.

8. *Mixtures.*—The volumes of cement, sand and broken stone in all mixtures of mortar or cement used in the work shall be measured loose.

9. *Connections.*—In connecting concrete already set with new concrete the surface shall be cleaned and roughened, and mopped with a mortar composed of 1 part Portland cement and 1 part sand, to cement the parts together.

10. *Arches.*—The concrete for the arches shall be started simultaneously from both ends of the arch and shall be built in longitudinal sections wide enough at least to include two steel ribs and of sufficient width to constitute a day's work. The concrete shall be deposited in layers, each layer being well rammed in place before the previously deposited layers shall have had time to set partially. The work shall proceed day and night continuously if necessary to complete each longitudinal section. The sections while being built shall be held in place by substantial timber forms normal to the centering and these forms shall be removed when the section has set sufficiently to admit of it. The sections shall be connected as specified above and also by steel clamps or rib connections built into the concrete.

11. *Drainage.*—Provision for drainage shall be made at each pier as follows: A wrought-iron pipe of sufficient diameter shall be built into the concrete, extending from each space over pier to the soffit. The surface of concrete over piers shall be so formed that any water that may seep through fill above will be drained to the pipes. The line of drainage will be covered with a layer of broken stone and the top of the pipes will be provided with screens to prevent clogging.

12. *Steel Ribs.*—Steel ribs shall be embedded in the concrete of the arch. They shall be placed at equal distances apart, and be of the number shown on plans. All steel must be free from paint and oil and all scale and rust must be removed before embedding in the concrete. The tensile strength, limit of elasticity and ductility shall be determined from a standard test piece cut from the finished material and turned or planed parallel. The area of cross section shall not be less than ½ inch. The elongation shall be measured after breaking on

an original length of 8 inches. Each melt shall be tested for tension and bonding.

Tests pieces from finished material prepared as above shall have an ultimate strength of from 60,000 to 68,000 pounds per square inch, an elastic limit of not less than one-half the ultimate, shall elongate not less than 20 per cent. in 8 inches, and show a reduction of area at point of fracture of not less than 40 per cent. It must bend cold 180 degrees around a curve whose diameter is equal to the thickness of the piece tested, without crack or flaw on convex side of bend. In tension tests the fracture must be entirely silky.

13. *Rivet Steel.*—Test pieces for finished material, prepared as above described, shall have an ultimate strength of from 54,000 to 62,000 pounds per square inch, an elastic limit of not less than half the ultimate strength, shall elongate not less than 20 per cent. in 8 inches and show a reduction at point of fracture of not less than 50 per cent. It must bend cold 180 degrees and close down on itself without fracture on convex side of bend. In tension tests the fracture must be entirely silky.

14. *Centering.*—The contractor shall build an unyielding false work or centering. The lagging shall be dressed to uniform size so that when laid it shall present a smooth surface, and this surface shall conform to the lines shown on the drawings. The center shall not be struck until at least 28 days after the completion of the work. Great care shall be shown when lowering the center so as not to throw undue strains upon the arches. The tendency of the centers to rise at the crown as they are lowered at the haunches must be provided for in the design, or if not, the centers must be temporarily loaded at the crown and the load be so regulated as to prevent distortion of the arch as the work progresses.

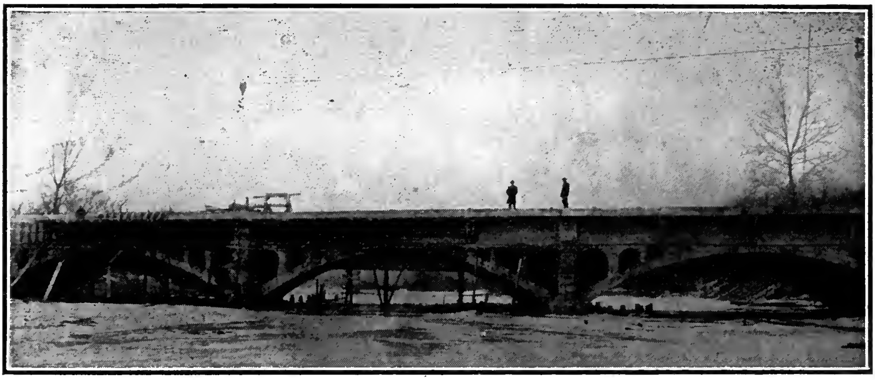
15. *Facing.*—When concrete facing is used, all piers, abutments and spandrel walls shall be built in timber forms. These forms shall be substantial and unyielding, of the proper dimensions for the work intended, and all parts in contact with exposed faces of concrete shall be finished to a perfectly smooth surface, by plastering or other means, so that no mark or imperfection shall be left on the work.

16. *Waterproofing.*—After the completion of the arches and spandrels and before any fill is put in, the top surface of the arches, piles and abutments and the lower 6 inches of the spandrel walls shall be covered with a suitable water-proof material so as to exclude water effectually.

17. *Fill.*—The space between the spandrel walls will be filled with sand, earth, cinders or other suitable material and

be thoroughly compacted by ramming, steam road roller, saturating with water or other effective means and be finished to the proper grade to receive the curbing and pavements.

18 to 20. *Paving.*—All curbing, sidewalks and asphalt pav-



REINFORCED CONCRETE AQUEDUCT OF INDIANAPOLIS WATER COMPANY.

ing shall be executed according to the plans and according to the standard specifications on file in the office of the Board of Public Works.

REINFORCED CONCRETE GIRDERS.

The Forest Park bridge for the Wabash railway in St. Louis, Mo., was greatly limited as to cost and the design provided for reinforced concrete abutments and curved wing walls, the cost of which could be reduced to a minimum; the fact that it is a bridge over a roadway aiding by reducing the necessary foundation. The overhead structure is a through plate girder with reinforced concrete slab floor, the girders being hidden from view from the roadway by ornamental reinforced concrete girders supported from the main girder. The specifications for the abutments require 1:2:5 broken stone concrete reinforced with Johnson bars, and the abutment is a vertical wall about 2 feet thick, with horizontal reinforcing bars spaced to suit the stresses and vertical bars every two feet. This wall is set on and thoroughly connected to a floor with double reinforcement, about 15 feet wide and projecting 2 feet outside the wall. It is also connected with the floor by buttresses about 8.5 feet long at the bottom and reducing to length suffi-

cient to carry the seat for the plate girders. These buttresses are thoroughly bonded to the wall and are about 14 feet apart. The wing walls are of similar construction, reducing in height and curving to ornamental pier lamp posts. The filling on the floor of the abutment furnishes weight for holding it in place and resisting the thrust of the earth pressure. For forming the vertical faces 2 by 6-inch studding was set up on proper batter and ⅞-inch dressed tongued and grooved lumber was nailed to it. The panels and the ashlar corners were provided for by setting the dressed form boards forward on strips or setting them back as required.

The floor of the bridge is made of slabs 8 inches thick, supported on the steel floor beams, each slab being reinforced with two sets of corrugated bars near upper and lower surfaces. The bars were supported and kept in proper spacing during construction by means of notched boards of proper height, set at the ends of the slab.

In constructing the ornamental girder, the reinforced concrete floor was first laid between the brackets. When this had set the forms were set for the ornamental solid paneled part of the girder. The studding was 2 by 4-inch lumber lined with matched and planed lumber with added layers and molded strips to give the panels and the molded edges their proper form. The form was filled with 1 to 3 mortar in which were embedded corrugated bars as reinforcement to carry the weight of the concrete from bracket to bracket. The railing on top of this girder was constructed separately. The balusters were cast in plaster molds made by forming a box about a wooden model and filling it with a wet mixture of 1 part plaster of paris and 1 part Portland cement. This cast was divided into three pieces by three sheets of galvanized metal inserted in the mold box for this purpose. When fully set the inside surface of the plaster mold was covered with a coat of shellac. This mold being assembled, a ½-inch corrugated rod was set vertically in the center and a 1:3 Portland cement mortar mixed wet was poured in and allowed to harden. The ornamental urns and balls were made in similar molds. The railing posts at the quarter points, forming panels in the railing, were molded in three sections and then set in place. Those

at the ends were molded in place, seven separate sections and operations being required to complete the design. The hand rail was cast in sections and set in place.

The cost of the ornamental girders was about $1,000, made up as follows: Balusters, 60 cents each; intermediate posts with urns, $12 each; end posts, $75 each; hand rail, 40 cents a linear foot; railing base, 45 cents; frieze and coping, $2 a linear foot; floor, 25 cents a square foot.

The River Avenue bridge over White River at Indianapolis, Ind., built by the Marion County Commissioners, is of similar design to the above, except that it has five 80-foot spans, has a 40-foot roadway with double street car tracks between the plate girders and the ornamental concrete girders are outside of and in part support 8-foot concrete sidewalks. The following extracts are made from the specifications:

Concrete Girders. The concrete girders for sidewalks shall be of a size and design shown on plans. The concrete to be of a quality hereinafter specified, and shall be reinforced with corrugated bars.

Sidewalks. The sidewalks shall be of reinforced concrete and shall be laid in a manner satisfactory to the engineer.

Roadway. The roadway shall be of reinforced concrete and paved with first-class vitirfied brick upon a two (2) inch cushion of sand. The quality and laying of the brick to be in accordance with specifications used by the City of Indianapolis.

Joist Seats. The joist seats and mud walls shall be of concrete, as shown on drawings.

Balustrade. The balustrade shall be molded in sections and placed in position after they are thoroughly seasoned, all joints to be neatly pointed with Portland cement mortar, the proper expansion joints to be provided for, as shown on drawings.

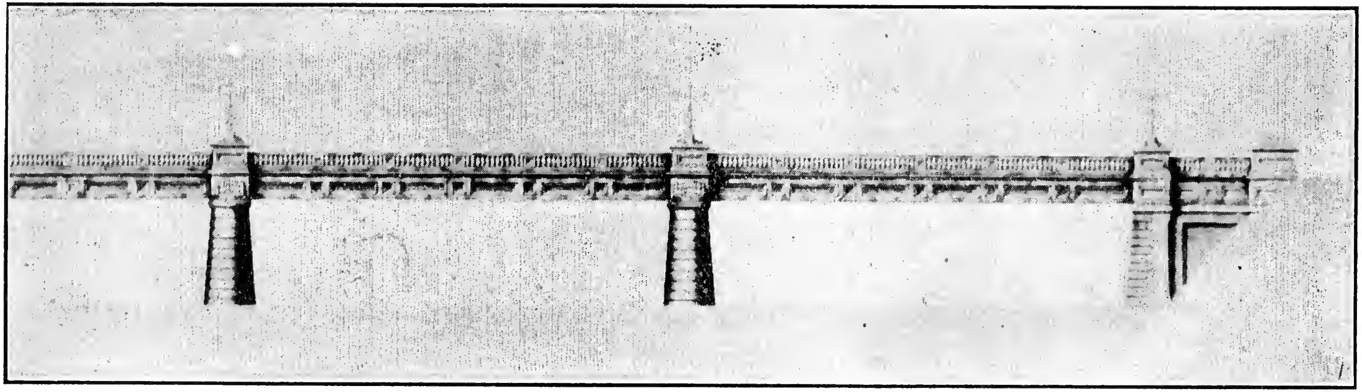
Buttresses. The buttresses over the piers shall be molded in proper forms and be of the design shown on drawings.

Concrete. The concrete for the various parts of the work to be as follows:

For the girders, to be a mortar of one (1) part Portland cement and three (3) parts clean, sharp sand.

For the sidewalks, one (1) part Portland cement, one and one-half ($1\frac{1}{2}$) parts clean, sharp sand and two and one-half ($2\frac{1}{2}$) parts crushed gravel that will pass through a one-half ($\frac{1}{2}$) inch ring.

For the roadway, one (1) part Portland cement, two (2)



REINFORCED CONCRETE GIRDER, RIVER AVENUE BRIDGE, INDIANAPOLIS, IND.

parts clean, sharp sand and four (4) parts crushed gravel that will pass through a one (1) inch ring.

For the pedestals, buttresses and balustrade, one (1) part Portland cement, one and one-half ($1\frac{1}{2}$) parts clean, sharp sand and two and one-half ($2\frac{1}{2}$) parts crushed gravel that will pass through a one (1) inch ring.

For the joist seats and mud walls, one (1) part Portland cement, three (3) parts clean, sharp sand and five (5) parts gravel that will pass through a two and one-half ($2\frac{1}{2}$) inch ring.

All concrete to be machine mixed and placed in position in a manner satisfactory to the engineer. All materials to be measured loose and proportioned as above specified.

Mortar Facing. All concrete surfaces exposed to view or to the weather shall have a mortar face of a minimum thickness of one (1) inch. The mortar facing must in every case be built up with the concrete, and no plane of demarcation or any plastering will be allowed. The mortar shall be composed of one (1) part Portland cement and two and one-half ($2\frac{1}{2}$) parts sand, measured loose.

Steel Bars. All steel bars used for reinforcing concrete shall be corrugated, and of a size and design shown on the drawings; must be free from rust, scale or oil, and be spaced as shown on plans.

Forms. The contractor shall build substantial forms for the roadway and sidewalks, the same to be properly braced and in conformity to the lines shown on drawings.

Casing. The forms for casing all concrete work shall be substantial and of timber of such thickness and stiffness and so braced that they are unyielding when the concrete is placed and rammed next to them. The forms for the various concrete structures shall be truly established and maintained by the contractor, so that the completed work shall conform in dimensions and position to the plans. In order to attain a smooth and satisfactory finish of all concrete surfaces exposed to view, the forms shall be plastered to a perfectly smooth finish with rock plaster, stucco, or other plastering material that will adhere to the forms. Before the concrete is deposited against the forms the plastered surfaces shall be coated with a soap sizing sufficient to prevent the plaster from sticking to the concrete. No plaster need be used whenever the width and length of one planed board or plank of well-seasoned timber will cover the whole surface of any plane, but no board marks or stains caused by wood acid or other imperfections will be allowed.

Workmanship. All copings, moldings, scroll work and exposed faces of the concrete work must conform to the lines on

the drawings. No patching or plastering will be permitted, and work showing defects after the casing has been removed must be replaced by new and perfect work.

The entire work must be built by expert workmen; no experimenting will be allowed. The contractor must satisfy the engineer as to the experience of the workmen in charge, and their ability to do first-class work.

Cement. The cement shall be equal to the best American Portland, the brand to be approved by the engineer. Specimens prepared for a mixture of one (1) part cement and three (3) parts clean washed sand shall after seven days develop a tensile strength of not less than 150 pounds per square inch, nor less than 220 pounds per square inch after 28 days. All cement shall be kept housed and dry until wanted in the work.

Immediately after being awarded the contract, the contractor for the super-structure must confer with the contractor for the sub-structure, and they shall agree upon the same brand of cement for both super-structure and sub-structure.

FINISHING CONCRETE SURFACES.

The following suggestions regarding specifications for finishing concrete surfaces and constructing ornamental concrete bridge work are made by W. J. Douglas, of Washington, D. C., in Engineering News:

The coping should preferably be cast on the ground and set in place; but if for economical reasons this is not practicable, it should be cast in place in alternate sections of about 4 to 6 ft. I would suggest in this connection that it might be well to use lime mortar rather than cement in these joints; this will make the joints of the coping open rather than crack the coping itself.

In most cases where the sinking of the crown was of any magnitude, this sinking had carried the parapet or balustrade down with the crown, with the result that from the sidewalk of the bridge the sinking was much in evidence and very disagreeable to the eye. In order further to guard against this aesthetic fault I would suggest that the balustrade or parapet be built after the arch has been struck.

From a careful inspection of cement balustrades and parapets, with some little experience in the execution of such work, I believe that concrete railings should not be built, because they will not bear the close inspection, which from their position they must necessarily receive. In the plans for our Connecticut Avenue bridge we have used granite coping and granite posts rather than use concrete. Even with the greatest care we have as yet been unable to cast concrete with a cement

face without having hair cracks appear in the surface. The hair cracks of course are not serious structurally, but to the layman, who has a right to criticize the work, they are invariably objectionable and necessarily reflect on the engineer responsible for the work.

Where the concrete railings or parapets are essential architecturally or economically, I believe much better results can be obtained by not facing the concrete with mortar at all where the design permits such treatment. In this case the work should be finished either by brushing out the mortar with wire brushes while the mortar is green, which gives a good rustic finish, or by tooling.

If a mortar face is desired, I believe that it is essential to use a coarse sand, low in silt, and a mortar somewhat leaner in cement than is the custom.,It seems to have been the custom in the past to use a richer mortar in the balustrades or parapets than in the facing of the arches and spandrel walls, in consequence of which such balustrades are invariably hair-cracked while the balance of the bridge is in excellent condition. (From the best avaliable data I am advised that in some cases the mortar has been used as rich as 1:1; but I think that it would be better to use 1:3 or 1:4.)

In many cases where the balustrade is hair-cracked and the balance of the bridge is in first-class shape, I attribute the hair-cracking largely to the fact that the balustrade has been finished by floating on a thin skin of mortar in order to get a better finish. This practice I know from personal experience to be bad, and where you use exceptionally rich mortar, say 1:1½ or 1:2, it is fatal. I believe the best way to treat the surface is to tool it after taking off the form, in order to take off the form marks and to give texture to the structure. This tooling further carries off the efflorescence which so frequently works to the face, and this treatment further obscures the hair cracks if they develop. Mr. Quimby, Engineer of Bridges of the City of Philadelphia, gets a very nice finish with an ordinary scrubbing brush. Form marks are objectionable to the eye, but if economy prevents the tooling or brushing of the surface, in my judgment it is better to leave them on rather than attempt to cover them up by floating. In fact for such work as river piers, which do not have to bear close inspection, I would recommend leaving the form marks on and believe that the best result is obtained by simply spading the concrete and omitting the mortar face. The bridge at Dayton is an excellent specimen of this class of work.

I believe, though possibly from insufficient data, that con-

crete which has been mixed wet, commonly called "soup," gives the best results.

I have for the last year or so been in favor of casting concrete blocks, particularly when of ornate design, in sand; but I do not feel fully convinced that there are advantages other than economy in casting in sand, if the concrete cast in wood or iron or plaster is kept wet. In the case of iron or plaster forms this can not be done except by removing the forms as soon as set, say fifteen hours, and properly protecting the product immediately upon such removal.

It is unfortunately a fact that in nearly all the concrete and concrete steel bridges which have been built, the profession has not made sufficient allowance for expansion. In steel bridges expansion seems to take care of itself, but in concrete and concrete-steel work it is a matter of vital importance. Errors in design should be rather on the side of too much probable expansion rather than too little. The Quarry Road bridge, which was built in Washington several years ago, is not above criticism in this respect. The spawling at the joint of the hand rail and rail base and the coping is sufficient warrant of the insufficiency of expansion joints. Another point worth noticing in the Quarry Road bridge is, that the rail itself has a camber, and a couple of summers ago the rail rose, when the bridge rose, about ½ inch (due to expansion); but in the winter when the bridge went back to its normal level the hand rail stuck fast and pulled away from the balustrade. This indicated two things: one that a camber in the hand rail is not a good thing to build and if built at all care should be taken to overcome the trouble due to expansion.

The use of metal pipes for draining the fill above the arch is bad practice where the soffit of the arch is subject to the inspection of the public, on account of the staining by the rust. Metal trimming of any kind other than bronze should be reduced to a minimum for the same reason. The drainage of the arches of the spandrel walls should be carefully studied, as in many cases the seepage of the water through the concrete discolors the cement face very much. I believe that one of the best methods of waterproofing is tarring, and where this is backed up with four or five inches of puddle clay the walls are almost certain to be dry. The back fill of a concrete bridge should never be puddled; as even with the best waterproofing it is highly probable that the face of the bridge will be discolored by the seepage of the water carrying some silt with it.

The bonding of a thick wall of concrete with a thin one nearly always causes the thin one to crack and is a point of decided moment in designing work of concrete. The doweling

of iron railings into concrete should be avoided if possible, and where it is not possible the dowels should be small.

Where refuge bays or observation places are made in a concrete parapet, expansion joints must be made where the straight reach of the parapet abuts against the portion which forms the bay, for the thrust of the straight reach will invariably crack the parapet of the bay.

Asphalt roadways and cement sidewalks should not be placed on a bridge with an earth fill over the arch for at least two years after the completion of the fill and consequently the entire bridge pavement should be placed under a separate contract from the bridge proper. About 33 per cent. of the masonry bridges inspected have badly cracked pavements, due to paving before the fill has fully settled.

CONCRETE SLAB CULVERTS AND BRIDGES.

The following directions for making reinforced concrete culverts and bridges in horizontal slab form are issued by the State Engineer of New York for use in the highways of that State:

Stone flagging or concrete slabs supported by steel I-beams or rails should be used in preference to plank for covering culverts having less than eight or ten feet span.

Provide a mixing bed 8 ft. wide and 10 ft. long formed of smooth boards laid close, or of sheet iron. Never mix mortar or concrete on the ground. Make an open box 6 ins. deep, 2 to 3 ft. wide and from 3½ to 4½ ft. in length, as the span may require. Whenever the necessary width of opening exceeds 3 ft., I-beams of steel must be used to span it, and these must be placed 2 to 3 ft. between centres, this distance varying inversely with the width, and the slabs made to span this distance between the centers of the beams. Provide expanded metal of gauge No. 4, formed of steel 3-16-in. thick, 5-16-in. wide, in meshes 6 ins. wide and 12 ins. long and weighing 1.1 lbs. per sq. ft., and costing 5 cts. per pound, and cut into sheets of sufficient size to nearly cover the proposed slabs, being careful that the 12-in. mesh crosses the span.

To make the concrete, use one part loose Portland cement, two and one-half parts sand and five parts broken stone or gravel not exceeding 1-in. in size, all being measured in loose bulk. If stone from a crusher is used, screen out the fragments larger than 1 in., allowing the dust to act instead of one part of sand. If gravel is to be used and is not clean, it should be washed in running water until the water runs away clear. Before using any cement, blend the contents of several bags or barrels— about five—so that if one bag or barrel is poor it will

be mixed with four good ones. Thoroughly mix the blended cement and the proper amount of sand before wetting; then add enough water to make a thin mortar which is not thin enough to run; dampen the broken stone or gravel; and then spread the proper quantity of the dampened stone or gravel upon the mixing bed in a 4-in. layer, and cover it with the mortar; mix thoroughly by turning with shovels or working with hoes until all fragments are coated with mortar. The mass thus formed should flatten and quake when put in a wheelbarrow or pail, but should not be fluid. Spread over the bottom of the box a coat of mortar followed by a coat of fine concrete making a layer 1¼ ins. thick after ramming, and upon this lay the sheet of expanded metal and embed it in the soft concrete by ramming, using care that the 12-in. length of the mesh lies with the length of the span of the slab when it shall be put on the culvert. Fill the box, working the stone from the sides with a trowel so that the edges will have a smooth surface; ram thoroughly until no stones or gravel can be seen and until the wet mortar comes to the top, and also smooth the top with the trowel. Keep this covered from the sun and wet it night and morning for a week until hardened, when it can be easily taken from the box. After it has set for an hour, scratch the word "Top" in large letters in the soft mortar, so that it may sure be thus laid in the work, as the slab will have little strength if laid with the embedded metal up. Do not make concrete in freezing weather, or else make it where it can be protected from frost. Such slabs can be made in winter by making them in a warm place free from frost and storing them for use until they are set and hard.

The flag-stone or concrete-slab cover can be covered by the road material, and if the culvert is properly built there will be no expense for maintenance, as is the case with a plank top. No culvert should be built less than 2 ft. in width so that it may easily be kept free from obstructions at all times. The bottoms of all culverts should be given sufficient fall to send the water out of them quickly. The bottoms, and spaces three or four feet wide at the inlets and the outlets, should be paved to prevent undermining, using flat stones set on edge and close together with the joints filled with coarse sand or fine gravel, or using cobbles properly embedded. The side ditches should also be similarly paved where long grades of 5 per cent. or over occur.

For culverts or short bridges having a span of less than 25 feet, it is usually most economical to use steel I-beams, covered with flagstones or concrete slabs.

In order to give proper support to the upper or compression

flanges of the I-beams, each beam should be tied to each adjacent beam with ¾-in. round tie rods spaced not over 5 ft. apart. The centers of these rods should be 2½ ins. below the tops of the beams and the two rods in any line which meet in any beam should be spaced 2½ ins. between centers.

The concrete slabs should be made with a shoulder ½-in. high along each edge, with not more than ⅛-in. clearance against the upper flange of the beam. The boxes in which the slabs are made should be constructed so as to provide these shoulders. The slabs, when finished, will be 5½ ins. thick at edges and 6 ins. thick elsewhere.

All I-beams should receive two coats of good paint. The beams should be carefully cleaned before the paint is applied, and the paint should be well brushed in.

TABLE SHOWING SIZES AND WEIGHTS OF I-BEAMS TO BE USED FOR VARIOUS LENGTHS OF SPAN FOR BRIDGES OR CULVERTS, USING STONE OR CONCRETE SLABS.

Depth of I-beam. Inches.	Width of Flange in inches.	Weight of I-beam per ft. of length Pounds.	Thickness of Web of I-beam. Inches.	Limiting Lengths of Span: I-beams spaced 2 ft. between centres.		I-beams spaced 3 ft. between centres.	
				ft.	ins.	ft.	ins.
5	**3**	**9¾**	**0.21**	**4**	**6**	**3**	**6**
5	3 1/8	12¼	0.36	5	0	4	0
5	3 5/16	14¾	0.50	5	6	4	0
6	**3 5/16**	**12¼**	**0.23**	**6**	**6**	**5**	**0**
6	3 7/16	14¾	0.35	7	0	5	6
6	3 9/16	17¼	0.48	7	6	6	0
7	**3 11/16**	**15**	**0.25**	**8**	**6**	**7**	**0**
7	3¾	17½	0.35	9	0	7	6
7	3⅞	20	0.46	9	6	7	6
8	**4**	**18**	**0.27**	**11**	**0**	**8**	**6**
8	4 1/16	20½	0.36	11	6	9	0
8	4 3/16	23	0.45	12	0	9	6
8	4¼	25½	0.54	12	6	10	0
9	**4 5/16**	**21**	**0.29**	**13**	**6**	**11**	**0**
9	4 7/16	25	0.41	14	6	11	6
9	4⅝	30	0.57	15	6	12	6
9	4¾	35	0.73	16	6	13	6
10	**4 11/16**	**25**	**0.31**	**16**	**6**	**13**	**6**
10	4 13/16	30	0.46	17	6	14	0
10	4 15/16	35	0.60	18	6	15	0
10	5⅛	40	0.75	19	6	16	0
12	**5**	**31½**	**0.35**	**21**	**0**	**17**	**6**
12	5 1/16	35	0.44	21	6	18	0
12	5¼	40	0.46	22	6	19	0
15	**5½**	**42**	**0.41**	**27**	**6**	**23**	**0**
15	5 9/16	45	0.46	28	6	23	6
15	5⅝	50	0.56	29	6	24	6

The accompanying table shows the sizes and weights of I-beams which should be used to insure safety in culverts, when crossed by a ten-ton road roller. The figures in heavy

type indicate the economical sizes to use. The lengths given are the clear spans or distances between the side walls. The I-beams should be long enough to rest a foot on each wall. The spaces between and outside of the I-beams on top of the side walls should be filled with concrete or masonry laid in cement mortar. If care is taken to fill with mortar the joints between the flagstones or concrete cover blocks, the I-beams will last many years longer than they will if the drainage from the road is allowed to wet and rust them.

REGULATIONS FOR REINFORCED CONCRETE CONSTRUCTION, NEW YORK BUREAU OF BUILDINGS.

1. The term "concrete-steel" in these regulations shall be understood to mean an approved concrete mixture reinforced by steel of any shape, so combined that the steel will take up the tensional stresses and assist in the resistance to shear.

2. Concrete-steel construction will be approved only for buildings which are not required to be fireproof by the Building Code, unless satisfactory fire and water tests shall have been made under the supervision of this Bureau. Such tests shall be made in accordance with the regulations fixed by this Bureau and conducted as nearly as practicable in the same manner as prescribed for fireproof floor fillings in Section 106 of the Building Code. Each company offering a system of concrete-steel construction for fireproof buildings must submit such construction to a fire and water test.

3. Before permission to erect any concrete-steel structure is issued, complete drawings and specifications must be filed with the Superintendent of Buildings, showing all details of the construction, the size and position of all reinforcing rods, stirrups, etc., and giving the composition of the concrete.

4. The execution of work shall be confided to workmen who shall be under the control of a competent foreman or superintendent.

5. The concrete must be mixed in the proportions of one of cement, two of sand and four of stone or gravel; or the proportions may be such that the resistance of the concrete to crushing shall not be less than 2,000 pounds per square inch after hardening for 28 days. The tests to determine this value must be made under the direction of the Superintendent of Buildings. The concrete used in concrete-steel construction must be what is usually known as a wet mixture.

6. Only high-grade Portland cements shall be permitted in concrete-steel construction. Such cements, when tested neat, shall, after one day in air, develop a tensile strength of at least 300 pounds per square inch; and after one day in air and six days in water shall develop a tensile strength of at least 500

pounds per square inch; and after one day in air and 27 days in water shall develop a tensile strength of at least 600 pounds per square inch. Other tests, as to fineness, constancy of volume, etc., made in accordance with the standard method prescribed by the American Society of Civil Engineers' Committee may, from time to time, be prescribed by the Superintendent of Buildings.

7. The sand to be used must be clean, sharp grit sand, free from loam or dirt, and shall not be finer than the standard sample of the Bureau of Buildings.

8. The stone used in the concrete shall be a clean broken trap rock, or gravel, of a size that will pass through a ¾-inch ring. In case it is desired to use any other material or other kind of stone than that specified, samples of same must first be submitted to and approved by the Superintendent of Buildings.

9. The steel shall meet the requirements of Section 21 of the Building Code.

10. Concrete-steel shall be so designed that the stresses in the concrete and the steel shall not exceed the following limits: Extreme fibre stress on concrete in compression, 500 pounds per square inch; shearing stress in concrete, 50 pounds; concrete in direct compression, 350 pounds; tensile stress in steel, 16,000 pounds; shearing stress in steel, 10,000 pounds.

11. The adhesion of concrete to steel shall be assumed to be not greater than the shearing strength of the concrete.

12. The ratio of the moduli of elasticity of concrete and steel shall be taken as 1 to 12.

13. The following assumption shall guide in the determination of the bending moments due to the external forces. Beams and girders shall be considered as simply supported at the ends, no allowance being made for continuous construction over supports. Floor plates, when constructed continuous and when provided with reinforcement at top of plate over the supports, may be treated as continuous beams, the bending moment for uniformly distributed loads being taken at not less than $W L = 10$; the bending moment may be taken at $W L = 20$ in the case of square floor plates which are reinforced in both directions and supported on all sides. The floor plate to the extent of not more than ten times the width of any beam or girder may be taken as part of that beam or girder in computing its moment of resistance.

14. The moment of resistance of any concrete-steel construction under transverse loads shall be determined by formulæ on the following assumptions:

(*a*) The bond between the concrete and steel is sufficient to make the two materials act together as a homogeneous solid.

(*b*) The strain in any fibre is directly proportionate to the distance of that fibre from the neutral axis.

(*c*) The modulus of elasticity of the concrete remains constant within the limits of the working stresses fixed in these regulations.

From these assumptions it follows that the stress in any fibre is directly proportionate to the distance of that fibre from the neutral axis.

The tensile strength of the concrete shall not be considered.

15. When the shearing stresses developed in any part of a concrete-steel construction exceed the safe working strength of concrete, as fixed in these regulations, a sufficient amount of steel shall be introduced in such a position that the deficiency in the resistance to shear is overcome.

16. When the safe limit of adhesion between the concrete and steel is exceeded, some provision must be made for transmitting the strength of the steel to the concrete.

17. Concrete-steel may be used for columns in which the ratio of length to least side or diameter does not exceed twelve. The reinforcing rods must be tied together at intervals of not more than the least side or diameter of the column.

18. The contractor must be prepared to make load tests on any portion of a concrete-steel construction, within a reasonable time after erection, as often as may be required by the Superintendent of Buildings. The tests must show that the construction will sustain a load of three times that for which it is designed without any sign of failure.

Several systems of reinforced concrete construction have been tested for their fireproof qualities and some of them have been accepted under Section 2 of the above, as more fully stated in the section regarding the fireproof qualities of concrete in the preceding chapter.

A REINFORCED CONCRETE FACTORY FLOOR.

The four-story factory of the Textile Machine Works, Reading, Pa., is about 50 by 200 feet in dimensions, and is built of reinforced concrete and brick. The floors are of Visintini beams, which are in form triangular braced lattice girders, 6 inches deep, 12 feet 1 inch long and 12 inches wide. Each beam is reinforced with three steel trusses, 4.5 inches apart. The upper horizontal rods of these trusses are ¼ inch in diameter, the lower horizontal rods are ⅜ inch and the diagonal members are bars 1 inch by ⅛ inch, with 6 sheet plates 1 inch wide to help the compression diagonals during handling while green.

The diagonal bars have holes punched in them through which the horizontal rods are passed. The beams are molded as follows in an adjoining building, where they are cured until ready to set in place in the floors. The bottom plank for the mold has attached to it triangular castings of the size and form for the openings in the web of the beam, on which are set hollow cast-iron cores of length the same as the width of the beam, 12 inches. The walls of the molds are 2-inch planks clamped together.

After the cast-iron cores are set over the bottom spacers, the walls of the forms are set up, and the concrete, which is mixed in a box in a very plastic state, is carried in pails to the forms and poured into them. At the proper depths the reinforcing trusses are inserted, whereby the cores act as spacers for the diagonals, but care must be taken not to have any of the diagonal straps come too near to them. After the forms are filled, they are struck off level and clamped at the middle by an iron strap fitting into a projecting pin. The beams are then left to set. Quite a number of forms are on hand, and about a hundred of cores. As they have to be cleaned and greased before use, the cores are pulled out by a lever device three to four hours after the forming of the beams. The beams are left in the forms for two days or more, and can be handled at once by hooks and triangular wooden bars fitting in the open spaces, the weight of one of the floor beams being 480 pounds, or about 40 pounds per square foot. The form boards and cores are then cleaned and greased, and are ready for fresh beams. The concrete is made of 1 part Portland cement, 1½ parts sand and 3½ parts broken trap rock, passing 1⅜-inch ring.

The beams are laid side by side, with ends supported on large girders of the same design. They are tied together by a set of 2 by 3 inch strips passed through alternate triangular spaces in the web and bolted to 2 by 4-inch plank on top of the beams by bolts passing up between the beams. The space between the planks is filled with cinder concrete and a maple floor is laid on top.

CONCRETE WALLS FOR FILTER BEDS.

The New Haven, Conn., Water Company has constructed a filter plant consisting of four acres of sand filter in twelve

beds, with operating gallery and clear-water reservoir. The walls, roof and floor are of concrete construction, the two latter reinforced with Ransome bars. The following description of the construction of the walls shows the method of allowing outlets for water from filled beds into those which are not filled.

The forms were made of spruce boards planed on the side next the concrete and were usually taken down at the end of about twenty-four hours in warm weather, but were left in place about two days in the colder weather of the late fall. Concrete work was suspended soon after freezing weather commenced. Special pains are taken to secure smooth surfaces and the efforts in this diretion have been successful. The 2-inch boards for the wall forms are slightly beveled on their edges, so that they can be driven close together, and the joints are calked, if necessary, with rags or jute to prevent the leakage of water and cement while the concrete is being deposited. The upright timbers are cut to fit the profile of the wall. As soon as the forms are removed any porous places discovered are promptly troweled with mortar and the surfaces of the walls are finished with cement grout rubbed with wooden floats. New concrete has been covered with burlap kept moist to insure satisfactory setting of the cement.

The walls are built in alternate monolithic sections 20 feet long of the full height. In the ends of sections which do not come against previously placed concrete a groove is formed about 6 inches wide and 6 inches deep. These grooves are smeared with asphalt pipe paint to prevent the adhesion of the concrete of the next section, so as to make sure that any crack caused by shrinkage due to the setting of the cement or changes of temperature will be formed at these places and will occur without breaking through the tongue of the next section and thus making a through passage for water. The thin parts of walls forming the sides of the grooves and the corresponding tongues are reinforced with twisted rods. Almost all these joints in the walls built during the past season have opened slightly, but during the leakage tests have passed only minute quanitities of water. None of these joints, however, were made at corners, but all corners are built monolithic with a portion of the walls extending in each direction.

The wall forms were at first braced with wooden struts in the usual way to hold them in place, but they floated up slightly, opening a crack at the bottom, through which the mortar of the concrete could escape. To counteract this tendency the form for each section was weighted with two large boxes filled with

stone. Then the braces were dispensed with and through bolts used to hold the sides of the forms against spreading. As an improvement bolts with short hook sections at each end, which could be taken out when the forms were removed, were tried.

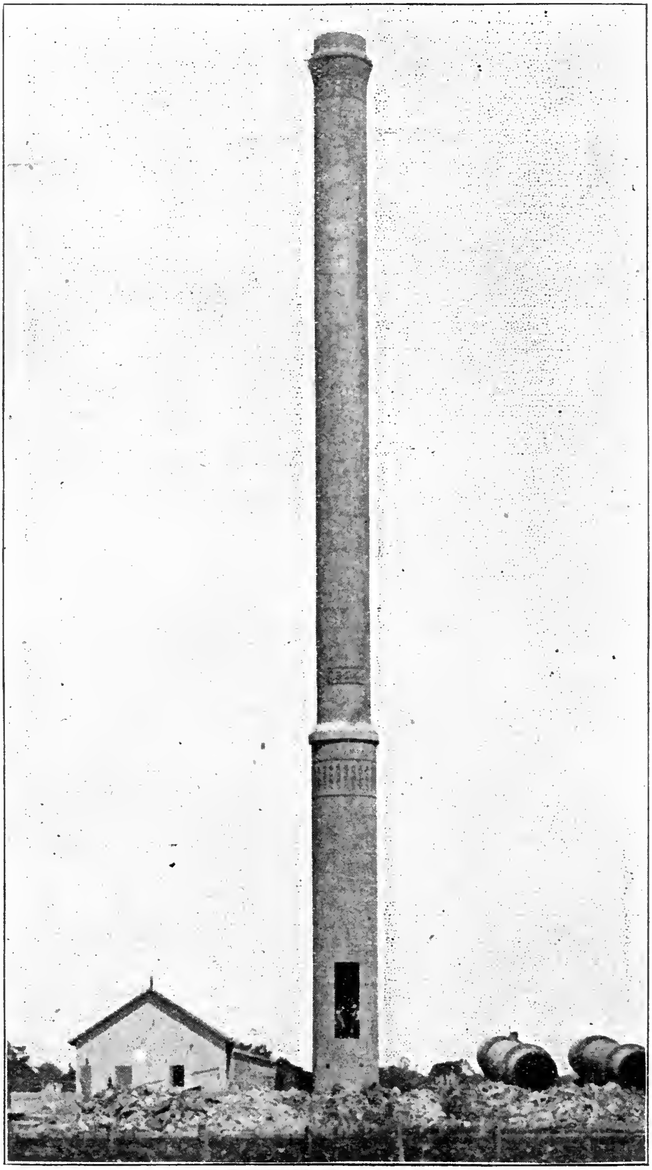
REINFORCED CONCRETE FILTER ROOF.

Later $\frac{7}{8}$-inch bolts made in three pieces united by two square cast-iron sleeve nuts placed $1\frac{1}{2}$ to $2\frac{1}{2}$ inches in from the face of the wall were adopted and are now used. The two short outer pieces are easily unscrewed and taken out while the concrete is green, and the sleeve nuts act as cut-offs to prevent the water following along the bolt and through the wall. Of course, the small holes made in the faces of the walls are promptly filled with mortar.

REINFORCED CONCRETE SEWER.

The following brief description gives the method of constructing a reinforced concrete sewer at Harrisburg, Pa.:

After the ditch was excavated to subgrade, the bottom was shaped to the proper profile and section. A small trench was then dug in the center, below subgrade, and the underdrain laid with its top about 3 ins. below the invert concrete. A wooden templet conforming to the shape of the invert was then accurately set to grade and line, about 12 ft. beyond the end of the completed invert, and the intervening section laid in the following manner: The concrete below the line at which the expanded metal was to be placed was thrown in and tamped. The metal, previously bent to the proper shape, was then placed with its ends extending up on both sides for lap with the arch metal, and the upper course of concrete placed



REINFORCED CONCRETE CHIMNEY, 182 FEET HIGH.

thereon. Before ramming it was roughly shaped up by means of a 14-ft. straight-edge, one end resting on the finished invert

and the other on the templet. After careful ramming the concrete was covered with a $\frac{1}{2}$-in. coat of 1:1 cement mortar, trued by the straight-edge and troweled smooth. Each 12-ft. section, as it was completed was tested for grade by the inspector.

The arch centers were $2\frac{1}{2}$x$2\frac{1}{2}$x$\frac{1}{4}$-in. steel angles bent to the proper shape and spaced 3 ft. 4 in. apart, their ends resting on wooden wedges placed on the side slopes of the invert. Two-inch planed pine lagging 10 ft. long was laid loose on these centers and coated with soft soap. The arch metal, previously bent to shape, was placed over this lagging and held at the proper distance by blocking with small stones. From the mixing-board the concrete was passed through a chute into a box supported on the lower bracing, from which it was shoveled into place. Wet concrete was used and forced through the metal against the arch center, the outside lagging being built up of rough lumber by outside ribs of pine. After three days the wedges were removed from under the steel ribs and the centering collapsed. The inside and outside were then gone over carefully and all imperfections in the concrete filled with 1:1 mortar. The backfill was kept 48 hours behind the arch construction.

REINFORCED CONCRETE CHIMNEY.

The following description of the chimney at the Leiter coal mines, Zeigler, Ill., may serve, except as to form of reinforcing bars, as an indication of the principles of design and construction used by several builders of such structures. A chimney of reinforced concerte 310 feet high is under construction.

The new Leiter coal mines at Zeigler, Franklin County, Ill., have completed a concrete-steel chimney, 154 feet 10 inches high, with a uniform inside diameter of 6 feet. The power house with which this chimney is connected at present contains three Heine safety water-tube boilers of 350 horse-power each, and supplies power to the mines and electric light to the town. The foundation of the chimney is carried to a depth of 9 feet 6 inches below the new grade and has a bearing 18 feet square. The foundation reinforcing consists of four layers of $1\frac{1}{4}$x$\frac{1}{4}$x$\frac{1}{4}$-inch steel T-bars. Two sets lie diagonally with respect to the sides of the foundation and at right angles to each other; the former are spaced 18 inches apart and the latter 12 inches.

The chimney proper is built up around vertical T-rods $1\frac{1}{4}$x$\frac{1}{4}$x$\frac{1}{4}$-inch in size, the bottom ends of which are turned outward and fixed between the layers of the foundation rein-

forcement bars, to securely anchor the structure. Every 18 inches these vertical rods, which are placed flange out, are banded outside by a T-ring 1x1x1⅛-inch placed with the flange inside. The vertical rods are in lengths of 20 to 27 feet breaking joints around the chimney and overlapping the ends 30 inches.

For 51 feet from the top of the foundation the chimney is built as two entirely separate concrete shells. The outer shell, 6 inches thick, takes the wind pressure, and the inner shell, 4 inches thick, allows for expansion changes with the high temperature of the flue. At the top of the inner shell 2½ inches is left for expansion vertically before contracting the outer shell to the 6-foot diameter. With a thickness of 5 inches this forms the single shell of the chimney from that point to the top. Between the two shells is left an air space of 4 inches, and about every 18 inches within this air space are blocks, the size of a half brick, projecting from the outer shell to within ½ inch of the inner, to guard against excessive relative displacement. At the bottom of the air space are four openings, each 4x4 inches in size, for allowing a circulation of air, which is quite free to pass into the body of the stack at the expansion joint above, the arrangement tending to keep the soot from settling into the air space.

The concreting forms consisted of two rings of six sections 3 feet wide, and fastened together with iron latches. These molds are held only by friction on the concrete and are disconnected before hauling to the next course. The flat top ring is a patent guide ring to hold the vertical steel rods in alignment through holes in it. This ring is made of two ¾-inch layers of wood and is pushed on up ahead of the concreting. It also carries the beam for the hoist-pulley. All material is hoisted inside the chimney.

The sand is Mississippi river sand, and the proportions are 1 cement to 3 sand where high compression exists, and 1:4 toward the top. The mixing was done with shovels on a platform, turned four to five times dry and at least three times wet. The concrete was mixed almost dry in very small quantities, and used immediately after mixing and tamped very hard. The outside finish is a wash of neat cement applied after the completion of the construction proper. The total weight of the chimney is 556,000 pounds.

REINFORCED CONCRETE STANDPIPE.

A reinforced concrete standpipe with surrounding tower also of reinforced concrete was built on the reservation at Ft. Revere, Hull, Mass., in June, 1903, and has given entire satisfac-

tion. The following is taken from a description of the structure by Leonard S. Doten:

The tower is octagonal in form, 33 ft. across the base and and 84 ft. high to the apex of the pyramidal roof. It consists principally of reinforced concrete, but the deeply recessed panels on the sides are of buff pressed brick. The winding stairs extending to the observatory above the stand-pipe are also of reinforced concrete. The roof is of wood, covered with slate. The foundation course is of 1:3:5 Portland cement concrete, extending only below frost, since it is founded on the "hardpan" or glacial drift. A part of the concrete foundation is occupied by a valve chamber 5x9 ft. in plan and 6 ft. high. The walls of the tower are 4 ft. thick at the base, with vertical faces to a height of 4 ft., above which the outer faces batter to a thickness of 2 ft. at 11 ft. above the floor, where there is a belt course 2 ft. thick. The external faces of these lower walls are divided by deep grooves into rectangles, giving the appearance of coursed masonry. The concrete in this part of the tower is reinforced by ¼-in. steel rods. Eight reinforced concrete columns, 38 ft. in height, rest on these base walls and carry a coping upon which the concrete floor of the observatory rests. The spaces between the columns are filled with the brick panels previously mentioned.

The stand-pipe, which is the most interesting portion of this structure, is 20 ft. in diameter and 50 ft. high, containing about 118,000 gallons. The walls are of concrete, 6¼ ins. thick at the base and 3¼ ins. at top, strengthened by steel rods embedded in the concrete. On the inside there are three coats of Portland cement plaster, having a total thickness of 1 in. The concrete was mixed in 1:2:4 proportions. The steel rods forming the horizontal reinforcement are ½-in. in diameter at the base, with two rings in each horizontal plane, the vertical distance between the rings being 1¾ ins. At the top there is but one ring in a plane and the vertical spacing is 7½ ins. The reinforcement of the body of the tank is completed by 5-16-in. vertical rods wired to the rings at points of contact, and spaced 8 ins. apart. In the bottom are two systems of ¼-in. rods crossing at right angles, spaced 4 ins. apart. The junction between the bottom and the sides is strengthened by ⅜-in. rods, 3 ft. 4 ins. long, placed radially, about 8 ins. apart. The cost of the tower and stand-pipe complete was about $12,000.

Reinforced concrete is used for light houses, piles, a hot well, the Harvard Stadium, wharf construction and many other pe-

culiar constructions in addition to those named in this and the preceding chapter.

PORTLAND CEMENT FOR WALL PLASTER.

In an article which appeared in Municipal Engineering Magzine, Mr. F. P. Van Hook presents the following methods of preparing wall plaster using Portland cement:

Portland cement mortar should be made as follows: Take good double strength lime, and slake in plenty of water, the water being put in the box first, 100 gallons of water to 200 lbs. (1 barrel) of lime. Do not stir the lime only enough to keep the large lumps from burning. It makes strong lime granulous to stir while slaking. It should stand a week or ten days before using. Put in 2½ bushels of good, clean hair to two barrels of lime. When ready to commence plastering, take one barrel of a good standard brand of American Portland cement to three barrels of lime. First mix the Portland cement with four parts of sand, mixing the sand and cement until they are thoroughly incorporated, turning over at least three times. Second, the lime mortar should be sanded to the right consistency to make a good, rich mortar. Third, mix the sanded cement with the lime mortar as it is used. It will take very little mixing to make a fine, tough mortar.

The "grounds"* to receive Portland cement mortar, fixing its thickness on the wall, should be ⅞ of an inch for lath work; for brick work or tile, ½ inch. The proper way to apply the mortar is to do "drawed" work—that is to run on a light coat first, then cover immediately with enough mortar to fill the grounds full, finishing same as lime mortar.

A good flat finish can be made by mixing Portland cement in lime putty, same as plaster of paris finish. For a granulated finish, screen the sand so it will be clean and uniform (white sand is the best), mix 1 part Portland cement, 1 part good lime putty, and add this to 6 or 7 parts sand. This is an excellent finish for public buildings where water colors are to be used.

Another very good way for mixing Portland cement mortar is to take 12 cubic feet of putty, sand to the right consistency for good mortar, then as it is used put 4 cubic feet, or 1 barrel, of Portland cement into the lime mortar, thoroughly incorporating it, as it goes to the workmen ready to put on. This Portland cement mortar makes a wall imper-

* "Grounds" are strips nailed at the end of lath and extending above the thickness desired for the coat, making a straight edge for the mortar.

vious to germs, and is especially adapted for hospitals, schools and where sanitary conditions are of most importance.

CEMENT STUCCO FOR WALLS.

First coat, one-half inch thick.

For best results, the wall should be furred off with spruce lath put on vertically, 12 inches apart and well nailed.

On these fasten firmly expanded metal lath.

Add fibre to the mortar for lathwork.

Wet thoroughly the surface to be plastered.

Mix 1 part non-staining Portland cement with 2 parts medium sand, 1 part fine sand and one-half part lime flour. When this coat has set hard, wet the surface thoroughly and apply the second coat (one-quarter inch thick) with a wooden float.

Mix 1 part cement as above, 1 part fine sand and 2 parts medium sand or crushed granite.

Before the second coat has set hard, it may be jointed to present the appearance of stonework.

A small addition of lime flour increases the adhesion of the mortar.

The finished surface should be protected for at least two weeks with canvas curtains or bagging saturated with water.

Defects are liable to appear on cement plastered walls when (1) to much cement is used; (2) not supplied with sufficient moisture; (3) not troweled sufficiently; (4) not protected from variations in temperature and drafts of air.

Plastering work should be done in the spring and never during freezing weather.

PLASTERING CISTERNS.

For plastering cisterns one part Portland cement to two parts sand will make a job that will be impervious to water, resist frost, and if well done, last for generations.

In cistern and cellar work, if there is any tendency of water to come in while the cement work is being done, that tendency must be removed by drainage or otherwise, as the water will press the cement aside before it is hard.

WATER-TIGHT CEMENT MORTAR.

By the use of lime putty, cement mortar is made more thoroughly water-proof, due to the great density of the mortar obtained, which hardens in the water, provided the water is not moving and not too cold or impregnated with acids.

The following proportions are best for water-tight mortar:

Cement.	Lime Putty.	Sand.
1 part	½ part	1 part
1 part	1 part	3 parts
1 part	1½ parts	5 parts
1 part	2 parts	6 parts

In making cement lime mortar, it is best to thoroughly mix the sand and cement dry, then screen the lime putty, mixed with water, into a mortar box and mix whole, adding more water if necessary till a uniform mortar of proper consistency is obtained.

The coating may be about ¾ inch thick.

MORTAR FOR BRICK AND STONE LAYING.

For common mortar that will harden quickly, reach greater strength at less cost than any other cement mortar, Portland cement should be used with slaked lime in the proportions given below.

The addition of slaked lime in small proportions makes the mortar "fat," "rich" and pleasant to work.

It greatly increases its adhesiveness and density, and contrary to general belief, also adds to the strength of such mixtures.

Any greater or any less proportion of lime to the mixtures given, will lessen the density, the tensile strength, the crushing strength and the adhesiveness.

The proper proportions are as follows:

Portland Cement.	Sand.	Lime Paste
1 part	5 parts	½ part
1 part	6 parts	1 part
1 part	8 parts	1½ parts
1 part	10 parts	2 parts

This lime paste or slaked lime is more than half water.

Soak the brick well before laying them in cement or the cement will have no water to make it harden.

DATA FOR ESTIMATES OF CEMENT WORK.

Experience of engineers and the comparison of various tables of amount and cost of materials required for various classes of work in which cement is an ingredient demonstrate that there are no exact rules by which the quantities required for a given work under a given specification can be definitely computed. It is easy to determine theoretically the amount of cement required for a mass of concrete, given the number of cubic yards to be filled, the percentage of voids in stone and sand, and the proportions of cement, sand and stone. The actual result may vary materially either in excess or deficiency from this theoretical quantity for many such reasons as the following:

The condition of the stone when voids are determined may vary as to moisture and compactness, the method and force used in consolidating the stone and its previous exposure to rain or sun not being uniform. The same may be true of the sand. The measurement of cement in original package or after emptying into a box will make some difference. The method of mixing materials is an important consideration, in general the more thorough the mixture the less the volume of the resulting concrete. The method of putting in place and the amount of tamping are also very important factors. The proportion of mortar to the voids in the stone is not an exact measure of the resulting volume. The most thorough work shows a shrinkage in volume of concrete from the volume of broken stone, unless the mortar is more than enough to fill the voids in the compacted stone. The same is true to some extent of gravel.

The following estimates of quantities are therefore simply approximate and may be exceeded or not attained, according to the local circumstances. While most of them are the results of actual experiment under practical conditions, the writer has checked but few of them in his practice, and presents them as being correct under a single set of conditions only, and approximately so in others. For rough estimates they will answer

satisfactorily. Each engineer or contractor is soon able to estimate his own quantities under the conditions of the methods he adopts better than he can from any statements of average results.

PACKING AND SHIPPING CEMENT.

Cement is packed in barrels, cloth sacks or paper bags, as ordered.

A barrel of Portland cement weights about 400 pounds gross, and should contain 380 pounds net of cement.

Portland cement, loose, weighs 70 to 90 pounds per cubic foot; packed, about 110 pounds per cubic foot.

A barrel of eastern natural hydraulic cement weighs about 320 pounds gross and should contain 300 pounds net of cement.

A barrel of western natural hydraulic cement weighs about 285 pounds gross and should contain 265 pounds net of cement.

Natural hydraulic cement, loose, weighs about 50 to 57 pounds per cubic foot; packed, about 80 pounds per cubic foot. Weights of cement and volumes of barrels are not uniform. Nearly all natural hydraulic cement is sold in sacks.

Slag cement weighs about 350 pounds gross, or 330 pounds net.

Cloth sacks ordinarily contain one-third of a barrel of natural hydraulic cement. The standard for Portland cement is one-fourth of a barrel. Paper sacks contain one-fourth of a barrel.

The following on cement packages is from a circular issued by a firm of general agents for cement:

Four paper bags or four cloth bags constitute one barrel or 380 pounds of Portland cement. The paper bags are charged to the customer at 2½ cents each or 10 cents ber barrel, and are of no further value. They have served their purpose in carrying the cement to destination and have given you service that is worth 10 cents per barrel. The cloth bags are charged at 10 cents each or 40 cents per barrel, and are worth 10 cents each or 40 cents per barrel if returned and received, freight paid, in good condition at the mill.

Here has been the misleading part to the consumer. While a few paper bags are liable to be broken in transportation with a corresponding loss of cement, the minimum loss of cement in a cloth bag is one pound to the sack or four pounds to the barrel. This amount remains unshaken from the bag. We have seen laborers so careless as to waste 3 per cent. of their cement in this manner. A paper bag is more easily handled—can be emptied with absolutely no loss of cement. It takes time

to untie a cloth bag and time costs money. A paper bag can be cut open with a hoe instantly.

The manufacturers and the railroads require bags returned to be freight prepaid. The minimum expense of such transportation from this district is 1¼ cent per barrel, which you pay. Use paper and save it.

The following table from Engineering News gives some idea of the variation in size of cement barrels. The first three brands named are American and the other two foreign Portland cements:

Portland cement brand.	(1) Capacity of bbl. cubic feet.	(2) Actual contents packed measure.	(3) Volume when dumped loose.	Difference between (1) and (2)	Difference between (2) and (3)
Giant	3.5	3.35	4.17	4%	25%
Atlas	3.45	3.21	3.75	4 "	18 "
Saylors	3.25	3.15	4.05	3 "	30 "
Alsen	3.22	3.16	4.19	2 "	33 "
Dyckerhoff	3.12	3.03	4.00	3 "	33 "

A carload of Portland cement usually means 100 barrels (40,000 pounds); 75 barrels is the minimum carload, or the same quantity by weight in cloth or paper bags.

When cement is ordered in cloth sacks the sacks are charged at cost, viz: 10 cents each, in addition to the cost of the cement; but when the sacks are returned to the works in good condition, freight prepaid, 10 cents is allowed for each, with a deduction of 2 cents for wear and tear in some cases.

For paper bags there is no charge, as they are not apt to be returned.

Empty sacks to be returned should be safely tied in bundles of ten or fifty—giving the name of the sender.

WEIGHTS AND MEASURES OF CONCRETE MATERIALS.

Sand weighs from 80 to 100 pounds per cubic foot dry and loose; from 90 to 115 pounds dry and well shaken.

Gravel weighs from 100 to 120 pounds per cubic foot loose and about 20 pounds more when well rammed.

Crushed limestone weighs about 90 pounds per cubic foot, varying somewhat either way with the size and amount of fine dust.

Copper slag, which has been used successfully where weight is wanted in concrete, weighs 120 to 125 pounds per cubic foot.

Concrete weighs about 140 pounds per cubic foot.

Quicklime weighs 64 pounds per cubic foot.

The weight of cinder concrete, composed of 1 part cement, 2½ of sand and 5½ of screened cinders, tamped on a wood center, will average ninety-five pounds per cubic foot. Eighty

pounds per cubic foot is often given as the weight of cinder concrete, and this is probably about right where the concrete is not tamped; but for all concrete tamped on wood centering, ninety-five pounds per cubic foot should be used in computing the weight of the floor and the strength of the steel beam.

Lime mortar and ordinary concrete will average 120 pounds per cubic foot.

Lime paste, about 50 per cent. water, one cubic foot of quick-lime and one cubic foot of water, make 1⅛ to 1¼ cubic feet of stiff lime paste.

Lime requires about 50 per cent. of its weight in water in slaking; natural hydraulic cement requires 28 to 31 per cent; silica-Portland cement, 22 per cent; Portland cement, 20 to 25 per cent.; slag cement, 22 to 28 per cent.; cement and sand mortars, 10 to 23 per cent. to complete the process of crystallization.

To make one cubic yard of Portland cement mortar the following quantities of cement and sand are required for the proportions stated, the cement being given in barrels, packed, and the sand in cubic yards:

Proportions.	Barrels of Portland Cement.	Cu. Yds. of Sand.
Neat cement	7.14	0
1 cement 1 sand	4.16	0.67
1 " 2 "	2.85	0.84
1 " 3 "	2.00	0.94
1 " 4 "	1.70	0.98
1 " 5 "	1.25	0.99
1 " 6 "	1.18	1.00

The following table shows the variations in amount of ingredients necessary to make a cubic yard of concrete. The table appears in the report of a committee on the use of cement made to the Association of Railway Superintendents of Bridges and Buildings and is made up from reports of such superintendents for various railways, giving their actual practice and observation:

PROPORTIONS.						AMOUNT OF INGREDIENTS.					
Natural Cement.	Portland Cement.	Sand.	Crushed Stone.	Gravel	Rubble	Natural Cement	Portland Cement	Sand	Crushed Stone	Gravel	Rubble
						Bbls.	Bbls.	Cu. Yds.	Cu. Yds.	Cu. Yds	Cu. Yds
1		1½	4			1.5		0.35	0.95		
1		2	4			1.9					
1		2	4½ or 5			1.5					
1		2	5 or 6 and	1 or 2 scre	enings.	1.0			1.00		
	1	1	2				3	0.39	0.79		
							1.5	0.45	0.96		
	1	2	4				1.4				
							1 6	0.42	0.83		
	1	2	5				1.0				
							1.2	0.35	0.95		
	1	2	4	3			1.0				
	1	2	5 or 6 and	1 or 2 scre	enings.		1.0		1.00		
	1	2	6						1.00		
	1	2½	6				1.0				
	1	3	4				0.92	0.36	1.00		
							1.0	0.51	0.87		
	1	3	5				1.1				
							1.2	0.5	0.9		
							0.96				
	1	3	6				1.2				
							1.0	0.5	1.00		
							1.2	0.55	1.00		
	1	3	6				0.82	0.37	0.72		.25
	1	3	6⅔				0.96	0.43	0.94		
	1	3	7½				0.9	0.35	0.95		
	1	4	7½				0.68	0.35	0.96		.25

The following table of approximate quantities of materials to make 100 cubic feet of finished concrete shows the reduction in amount of cement used if the ingredients are measured in the mixing box rather than in the original package:

Proportions of Cement to Aggregate.	Barrels of Cement When Proportioned by Barrels.	Barrels of Cement When Proportioned by Measurements.	Yards of Aggregate.
1 to 1	18.3	15.8	2.75
1 “ 2	11.6	10.	3.85
1 “ 3	8.7	7.5	3.95
1 “ 4	6.9	5.9	4.15
1 “ 5	5.6	4.7	4.30
1 “ 6	5.0	4.3	4.40
1 “ 7	4.4	3.7	4.45
1 “ 8	3.9	3.3	4.46
1 “ 9	3.4	2.9	4.47
1 “ 10	3.0	2.6	4.48
1 “ 11	2.8	2.4	4.50
1 “ 12	2.5	2.2	4.53
1 “ 13	2.4	2.0	4.55
1 “ 14	2.3	1.9	4.57
1 “ 15	2.2	1.8	4.59
1 “ 16	2.1	1.7	4.62
1 “ 17	2.0	1.6	4.63
1 “ 18	1.9	1.5	4.65
1 “ 19	1.8	1.4	4.68
1 “ 20	1.7	1.3	4.70

This table is given in the California Portland Cement Company's handbook.

See also tables on pages 123 to 133.

Materials for Concrete.—The following quantities of materials required for concrete on the Connecticut Avenue bridge, Washington, D. C., were determined by A. W. Dow and W. J. Douglas:

Concrete Class A.

4 bags=1 bbl. Vulcanite cement=378.25 lbs.=4.5 cu. ft.
9 cu. ft. sand.
20.25 cu. ft. stone.
Yielded 21.4 cu. ft. concrete when rammed into place.

Concrete, Class B.—1:2½:6 (broken stone).

4 bags=1 bbl. Vulcanite cement=378.25 lbs.=4.5 cu. ft.
11.25 cu. ft. sand.
27 cu. ft. stone.
Yielded 27.66 cu. ft. concrete when rammed into place.

Concrete Class B.—1:2½:3:3 (3 gravel and 3 stone).

4 bags=1 bbl. Vulcanite cement=378.25 lbs.=4.5 cu. ft.
11.25 cu. ft. sand.
13.5 cu. ft. gravel.
13.5 cu. ft. stone.
Yielded 27.66 cu. ft. concrete when rammed into place.

Concrete Class C. 1:3:10 (gravel).

4 bags=1 bbl. Vulcanite cement=378.25 lbs.=4.5 cu. ft.
13.5 cu. ft. sand.
45 cu. ft. gravel.
Yielded 45 cu. ft. of concrete when rammed into place.

One barrel of Portland cement will cover the following areas when used as plastering, with the various proportions of sand noted. These areas are slightly less than would be computed from the volumes of cement mortar in a preceding table on account of waste, filling of cracks and voids, etc.:

	Thickness of Coating.	Square Feet of Area Covered.
1 cement 1 sand	1 inch.	67
	¾ "	90
	½ "	134
1 cement 2 sand	1 "	104
	¾ "	139
	½ "	208
1 cement 3 sand	1 "	140
	¾ "	187
	½ "	280

From the Buckeye Cement Company's handbook is taken the following table of materials required for cisterns:

Diameter in Feet.	Capacity Gallons for Each Foot Depth.	For this Column Use Diameter of Digging.	For Each Foot Depth. For these Columns Use Diameter in Clear of Lining.			Bottom.	
						Bricks in Bottom	Plastering in Bottom Sq. Yds.
		Cu. Yds. of Digging.	Stone Lining 1 Ft. Thick (25 Cu. Feet.)	No Bricks in Lining—1 Thick.	Sq. Yards Plastering.	Use Diameter of Digging.	Use Diameter in Clear of Lining.
5	146	.75	.75	230	1.74	148	2.18
6	211	1.04	.88	275	2.09	215	3.14
7	288	1.42	1.00	320	2.44	292	4.27
8	377	1.86	1.13	375	2.79	382	5.58
9	476	2.36	1.26	410	3.14	483	7.06
10	587	2.91	1.38	460	3.49	596	8.72
11	710	3.52	1.51	500	3.84	722	10.56
12	846	4.19	1.63	550	4.19	859	12.56
13	992	4.92	1.76	590	4.54	1008	14.74
14	1152	5.70	1.88	640	4.89	1170	17.10
15	1325	6.54	2.01	680	5.24	1343	16.63

One barrel of Portland cement will lay about 60 square feet of cement walk under the first or general specification for cement walks given in the chapter on Specifications for the Use of Cement.

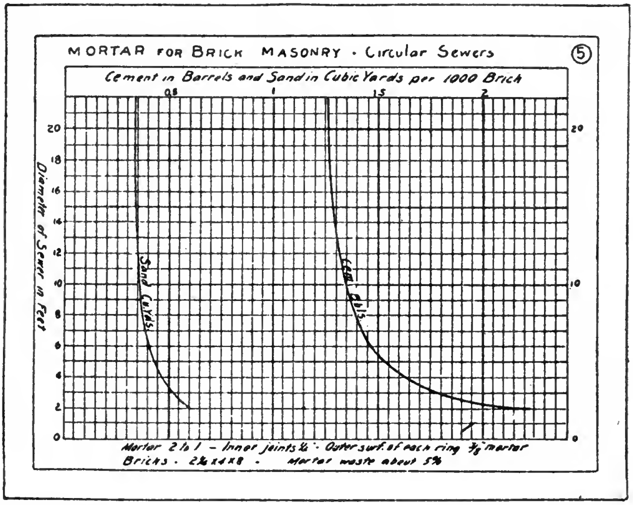
From the California Cement Company's handbook is taken the following table of quantities required for making cement pipe, as follows:

Inside Diameter Pipe.	Thickness of Pipe.	Approximate Proportions Cement to Sand and Gravel.			Number Feet Pipe to Cubic Yard Sand and Gravel.
		1 to 3	1 to 3½	1 to 4	
		Number of Lineal Feet of Pipe 1 Barrel of Portland Cement Will Make.			
8 in.	1 in.	61.11	71.30	81.48	137.50
10 in.	1 in.	50.00	58 00	66.66	112.50
12 in.	1⅛ in.	37 25	43 47	49.67	83 81
14 in.	1¼ in.	28.85	33 66	38.47	64.91
16 in.	1⅝ in.	19.20	22.40	25.60	43.20
20 in.	1¾ in.	14 45	16 58	19 21	32 51
24 in.	2 in.	10.58	12.34	14.10	23.80
30 in.	2½ in.	6.77	7.89	9.02	15.23
36 in.	3 in.	4.70	5.48	6.27	10.57

The volume of mortar in fractions of a cubic yard necessary to lay a cubic yard of masonry is as follows:

For Brickwork, ⅛-inch joints	.15
" " ¼ " "	.25
" " ½ " "	.40
" Ashlar, 20-inch courses	.06
" Squared Stone Masonry	.20
" Rubble Masonry	.25
" Concrete, broken stone	.55

Emmet Steece prepared the following diagram showing the amount of cement and sand required for sewer masonry:



In sewer work, one barrel of natural hydraulic cement used neat will lay the following lengths of pipe of the various sizes, pipe being in 3-foot lengths:

Size of Pipe.	Length 1 Bbl. of Cement Will Lay.	Size of Pipe.	Length 1 Bbl. of Cement Will Lay.
4	500	12	100
6	350	15	75
8	200	18	65
9	172	20	60
10	150	24	50

COST OF CEMENT WORK.

Concrete Paving for Reservoir.—Some detailed statements of actual cost of concrete with various proportions of ingredients will be of interest. On the Forest Hill Reservoir at Quincy, Mass., several classes of concrete were used, specifications for

part of which are given in a preceding chapter. Detailed accounts were kept and the following tables of cost were prepared:

279 cu. yds. Portland Cement Concrete, 1:2½:5.

	Quantities.		Cost per cu. yd.
Cement	1.35 bbl. @ $2.23		$3.010
Sand	.46 c yd. @ 1.13		.521
Stone	.74 " @ 1.13		.840
Lumber for forms, a M. ft	@ 20.00		.495
Labor: General expenses		.202	
Forms		.586	
Mixing and placing		1.147	
			1.955
Cost, per cu. yd. (total)			$6.821

284 cu. yds. Portland Cement Concrete, 1:3:6.

Cement	1.07 bbl. @ $2.23		$2.390
Sand	.44 c yd. @ 1.13		.497
Stone	.88 " @ 1.13		.994
Lumber for forms, a M. ft	@ 20.00		.127
Labor: General expenses		.154	
Forms		.214	
Mixing and placing		967	
			1.335
Cost per cu. yd. (total)			$5.337

400 cu. yd. American Natural Cement Concrete, 1:2:5.

Cement	1.25 bbl. @ $1.08		$1.350
Sand	.54 c yd. @ 1.02		.347
Stone	.86 " @ 1.57		1.350
Lumber for forms, a M. ft	@ 20.00		.090
Labor: General expenses		.08	
Forms		.10	
Mixing and placing		1.17	
			1.350
Cost per cu. yd. (total)			$4.487

615 sq. yds. Portland Cement Concrete, 1:2½:6½.

Cement	1.08 bbl. @ $1.53		$1.652
Sand	.37 c yd. @ 1.02		.377
Stone	.96 " @ 1.57		1.507
Lumber for forms, a M. ft	@ 20.00		.016
Labor: General expenses		.177	
Forms		121	
Mixing and placing		1.213	
			1.511
Cost, per cu. yd. (total)			$5.063

1,222 cu. yds. Portland Cement Concrete, 1:2½:4.

Quantities.		Cost per cu. yd.
Cement	1.37 bbl. @ $1.53	$2.09
Sand	.47 c yd. @ 1.02	.48
Stone	.745 " @ 1.59	1.17
Lumber forms	@ 20.00	.25
Labor: General expenses		.15
Forms		.26
Mixing and placing		1.53
Average cost, a cu. yd		$5.93

Slope Finish (with same Concrete).

Quantities.	Cost per yard. 3,600 sq. yds.	100 cu. yds.
Cement	$0.048	$1.710
Sand	.011	.390
Stone	.026	.960
Labor: Mixing and placing	.059	2.500
Average cost (total)	$0.154	$5.560

Portland Cement Plastering 6,822 sq. yds.

Cement	0.07 bbl. @ $1.53	$0.103
Sand	.012 c yd. @ 1.02	.012
Labor		.083
Burlap		.002
Average cost per sq. yd		$0.200

695 sq. yds. Portland Cement Granolithic Walk.

		Cost Sq. Yd.	Cu. Yd.
1. Stone foundation	232 cu. yds.		
Stone		$0.134	$0.40
Labor: Placing, etc		.502	1.50
Average cost		$0.636	$1.90
2. Concrete base	90 cu. yds.		
Cement	1.22 bbl @ $1.53	$0.242	$1.86
Sand	.50 c yd. @ 1.02	.066	.51
Stone	.84 " @ 1.57	.170	1.32
Labor		.450	3.48
Average cost		$0.928	$7.18
3. Top finish	695 sq. yds.		
Cement	.011 bbl. @ $1.53	$0.168	......
Sand	.22 c yd. @ 1.02	.022	......
Lampblack		.008	......
Labor		.149	......
Average cost		$0.341	......
Total average cost a sq. yd.		$1.905	

Concrete Bottom for Reservoir.—The bottom of the reservoir at Canton, Ill., was made of concrete 10 inches thick, in-

cluding a ¾-inch coat of Portland cement mortar. The materials used and the cost were determined as follows:

The concrete was mixed in the following proportions: 1 part Portland cement, 3½ parts clean, sharp sand and 7½ parts medium crushed rock, by measurement. These proportions were determined as follows: The voids in the crushed rock were found to be 40 per cent., in the sand 30 per cent., giving 12 per cent. for cement; dividing this by 12 gave 1 cubic foot of cement to 3½ cubic feet of sand, to 8½ cubic feet of crushed rock. Adding 10 per cent. of mortar to insure a good mixture we have 1 to 3½ to 7½. One 95-pound sack of cement contains 0.9 cubic feet, and is mixed with 3 cubic feet of sand and 6¾ of rock. We mixed the concrete in batches of 3 sacks of cement to 9 cubic feet of sand and 20¼ cubic feet of rock. The cement coat was mixed with 1 part cement to 2¼ parts of sand, and was spread and worked smooth with the trowel.

The concrete work cost $5.38 per cubic yard in place, as follows:

Medium crushed rock, 0.857 cubic yard, at $2.17	$1.86
American Portland cement, 0.586 barrel, at $2.50	2.14
Sand, 10.1 bushels (100 lbs. per bushel), at 5¾ cents	0.58
Labor, mixing and placing concrete, 10 cents per hour	0.80
Total	$5.38

Waterproofing for Reservoir.—W. C. Hawley gives some valuable data regarding cost of methods of waterproofing leaky concrete reservoirs.

In the first case a clear water well was plastered with mortar made with Portland cement to which 3 pounds of alum had been added for each barrel, mixed with 2 parts of sand to 1 of cement and wet with water in each 15 gallons of which 1¼ pounds of light colored soft soap had been dissolved. Two coats were applied, aggregating ½-inch thickness and the leakage was stopped. The cost per barrel of cement or per cubic yard of mortar was 57 cents for the waterproofing materials, *i. e.*, 2 pounds of soap with 24 gallons of water, 15 cents, and 12 pounds of alum, 42 cents.

In the second case a solution was made of ¾-pound of Olean soap to one gallon of water and another ½-pound of alum to 4 gallons of water. The surface of the concrete was washed and partly scrubbed and when dry the soap solution was applied boiling hot. After 24 hours the alum was applied, after an-

other 24 hours the soft soap again and after another 24 hours the alum again. The labor cost $200.88; superintendence, $30.13; soap, alum and brushes, $66.30; a total of $297.31. The area covered was 131,634 square feet, making the cost $2.26 per thousand square feet. A slight leak remained, which was probably through a crack and reduced later in amount.

In the third case the concrete lining of a new reservoir was waterproofed by using caustic potash and alum in the finishing coat, 2 pounds of potash and 10 pounds of powdered alum for 10 quarts of water. A batch of mortar used 2 bags of cement, 4 bags of sand and 3 quarts of the solution and covered 48 square feet ½-inch thick. The cost for potash and alum was $50.68 and the extra cost of putting it in the concrete was $20.50, a total of $71.18, for 74,800 square feet of surface, or 95 cents a thousand square feet. Too much potash must not be used as it weakens the concrete. The alum strengthens it. The sand must be clean. The face appears more compact than one of ordinary mortar.

Reinforced Concrete Dam.—A dam at Richmond, Ind., constructed by H. L. Weber, 120 feet long and about 6 high, cost $2,100.89, the cost being distributed as follows:

220 cu. yds. concrete in dam proper at $5.58........	$1,227.60
87 cu. yds. reinforcing old abutments and extra foundation	485.46
44 16-ft. piles, driven	320.00
53.5 yds. riprap masonry (labor, stone fill)..........	42.83
Gates for spillway and fish ladder...................	25.00

The gravel and stone cost 80 cents a cu. yd.
For each cubic yard in place:
Lumber cost 60.8 cents.
Pumping cost 27.5 cents.
Cement cost $1.485 ($1.60 a barrel).
Drift bolts, I-beams and incidentals cost 44.5 cents.
Labor of excavating and placing coffer-dam cost 96 cents.
Concrete and frames cost $1.007.
Making the total cost $5.58 as above.

One barrel of cement was used per cubic yard of gravel and large stones were embedded at intervals in the concrete.

Three tons of old scrap iron rods and cable were used in reinforcing, the value of which is not included.

Concrete and Brick Sewer.—The following is a detailed table

by William G. Taylor, of the cost of a sewer 1,610 feet long and 30 inches in diameter made of concrete for two-thirds the circumference, 6 inches thick at bottom and 7 inches at springing line, and reducing to 6 inches at the bearing planes of the brick arch completing the upper one-third of the sewer:

Each linear foot of sewer required 1.25 cu. yds. excavation and refill, 4 cu. ft. Portland cement concrete, and 1 cu. ft. brick masonry.

Excavation and Refill.

Excavation	$677.48
Bracing	52.47
Backfilling and resurfacing street	335 84
Pumping	1.00
Water boy	33 90
Kerosene	17.28
Boots	2 35
Lumber	69.00
Total	$1,189.68

Material excavated was gravel and clay.
Total volume excavated, 2,019 cubic yards.
Cost of excavation and refill was $0.589 per cubic yard.

Concrete Masonry.

Portland cement, 256½ barrels	$550.27
Labor, mixing and depositing 240 cu. yds	723.92
Cost of forms	45.00
Screening gravel (labor)	112.63
Gravel and sand purchased (gravel and sand mostly taken from excavation)	14.00
Carting	142.38
Miscellaneous items	21.32
	$1,609.52

Total cubic yards of concrete, 240.
Cost of concrete, $6.70 per cubic yard.

Brick Masonry in Arch.

Portland cement, 79 barrels		$178.54
Brick, 29,000		246.50
Forms		23.73
Labor, mason	$79.20	
Tenders	123.25	
		202.45
Carting		40.00
Incidentals		20.12
Total		$711.34

Total cubic yards brick masonry, 59.
Cost of brickwork in arch, $12.05 per cubic yard.
Cost of brickwork in manholes, $15.34 per cubic yard.

Reinforced Concrete Sewer.—T. C. Hatton reports the cost per linear foot of a concrete sewer reinforced with expanded metal in the following table. The sewer was 9 ft. 3 ins. in diameter and the concrete 5½ inches thick. The figures include

the concrete only, not the excavation, pumping, sheeting or refilling.

Cost of Placing Concrete.

1.31 bbls. Portland concrete, $1.30	$1.703
0.84 cu. yd. stone, $1.21	1.016
0.42 cu. yd. dust, $1.21	.508
Labor at 18¾ cts., including foreman	.987
Setting forms and metal	.045
40 sq. ft. of metal, 4 cts.	1.60
Plastering invert	.07
Cost of forms, 1,800 ft., per foot	.082
Total	$6.011

Reinforced Concrete Subways.—Three subways of 40, 60 and 160 feet long were built in the Elkhart, Ind., yard of the Lake Shore and Michigan Southern railroad, each having 30-foot arch spans, and 13-foot headway, with 28 inches thickness at crown. The arches were reinforced with Johnson bars 2½ inches from the extrados and intrados and spaced 6 inches apart. Concrete was 1 part cement, 3 gravel and 6 stone, the gravel coming from the foundations and being about one-half sand. The cost is detailed as follows:

			Av. cost per cu. yd.
Temporary buildings, trestles, etc		$ 752 33	$0 15
Machinery, pipe, fittings, etc		416 34	08
Sheet, piling and boxing		1,006 12	21
Excavating and pumping		1,619 74	33
Arch centers and boxing		3,528 92	73
Concrete masonry: Cement	$8,860 55		
Stone	1,788 50		
Sand	240 00		
Drain tile	103 03		
Labor	8,091 41		
		$19,083 49	3 95
Steel reinforcing rods		3,028 39	63
Engineering, watching, etc		508 40	11
Total		$29,943 73	$6 19
Contents, 4.833 cu. yds			

Cost of Making Hollow Concrete Blocks.—L. L. Bingham made a collection of data regarding cost of making hollow concrete building blocks in Iowa, from which the following figures are taken. These figures are reduced to cost per square foot of wall area for 10-inch block, which the blocks would lay.

The ranges in prices in various factories per square foot of wall are as follows:

Sand 0 to 4.5 cents, averaging 2 cents.

Cement (average price $1.60 a barrel), 3 to 7.5 cents, average 4.5 cents.

Labor (average day wages $1.83 for 48.5 feet product), 3.8 cents average.

Total average cost 10.3 cents a square foot of wall.

Rent, interest on cost of outfit, depreciation, supervision, cost of selling, loss in handling, etc., must be added to obtain the total cost of blocks. This is estimated for one average plant at 5 cents, making the total cost of making blocks 15.3 cents per square foot of wall. The selling price of 8 and 10 inch blocks ranged from 12¾ to 22½ cents, averaging 17½ cents for 8-inch and 20½ cents for 9 and 10-inch blocks per square foot.

The cost of mortar and labor of laying blocks in wall varied between 2½ and 9 cents, averaging 5 cents.

Cost of Cement Sidewalks.—Mr. Bingham also collected data on cost of cement sidewalks in Iowa. He found that sand and gravel cost 40 cents to $2.25 a cubic yard on the work, averaging 1½ cents a square foot. Cement at an assumed average price of $2 a barrel cost 3.6 cents a square foot with variations due to differences in proportions of cement and sand. Labor averaged 2.2 cents a square foot. Incidentals were estimated at 0.61 cents a square foot from Mr. Bingham's experience. This makes the total average cost very nearly 8 cents a square foot. Prices obtained ranged from 8 to 16 cents, most of them about the average of 11.5 cents.

LIME AND PLASTER.

Rich or so-called "double strength" limes are nearly pure oxide of calcium, obtained by burning nearly pure limestones containing from 1 to 6 per cent. of other ingredients. Common limes contain greater percentages, poor limes being obtained from limestones containing from 15 to 30 per cent. of sand, magnesia and other impurities. Pure limes when slaked increase in bulk, occupying even more than double the volume of the lime fresh from the kiln. Poor limes do not materially increase in volume in slaking. The limestones of this country are numerous and of all grades, those of the better grades being sufficiently well distributed so that but little "poor" lime need be placed on the market.

If the limestone contains clay a hydraulic lime may be obtained by burning, and if the proportions are correct a hydraulic cement is the result of calcination. Many of the hydraulic cements are obtained from limestones containing also a large proportion of magnesia.

The process of burning is so simple in theory, whether in intermittent or in continuous kilns, and the carrying out of the process successfully is dependent upon so many conditions of fuel, stone, weather and kiln, which vary continually, that it need not be described here.

The recent development of the plaster industry and the still more recent development of the Portland cement industry have materially modified the conditions in the building trades and the relative positions of lime, plaster, natural hydraulic cement and Portland cement are not yet fixed, and each is frequently used where another in the list would be more suitable or more economical. As a consequence, there is more or less uncertainty, especially in the older industries. The more careful study of the adaptability of the various materials will finally result to the benefit of all by putting each in its proper sphere and reducing the failures from misapplication of material on the one hand and the waste of money by use of more expensive materials than are necessary, on the other.

VARIETIES OF LIME.

The following by Geo. V. Rhines, in Municipal Engineering, gives some information regarding dolomitic or magnesia lime as compared with high calcium lime.

There are two principal forms of lime—one made from practically pure limestone known as high calcium lime, and the other made from dolomite known as magnesium lime. The latter contains about 40 per cent. oxide of magnesia which does not swell and give out heat to any appreciable extent when slaked, but which has strong cementing properties. This presence of magnesia is responsible for the preference of the mortar mixer or slaker for high calcium lime, as the calcium oxide will slake almost immediately on the addition of water in any kind of weather, and no skill whatever is required other than to see that the water is added often enough to prevent burning.

When the dolomite lime is used, it is necessary to add the water very gradually, and after the first supply is added, the mass should be agitated to prevent "drowning" until the heat is generated by the chemical action of hydration. It is then necessary, at the proper time, to add more water in such quantities as to allow this hydration to continue, but not enough to check the chemical action, which would cause lumps or "chestnuts" as they are called, to remain in the mortar. Furthermore, large stones or core are sometimes present in the dolomite limes, due to the fact that a much greater degree of heat is required to burn calcium carbonate than magnesium carbonate, and it is necessary to take out these stones before adding sand in the mixing box.

The calcium oxide swells considerably when hydrated, while the magnesium oxide does not. This gives the calcium lime a somewhat greater bulk, and as sand is invariably mixed by eye, as much being added as the mixer thinks sufficient to bring the mortar to proper richness, the result is a larger yield of mortar when the hot lime is used.

In order to compare the strength of the two limes, complete tests covering a period of one year were made by Mr. George S. Mills, architect, of Toledo, Ohio.

The results of the tests are given below.

TESTS OF COMPARATIVE TENSILE STRENGTH OF DOLOMITE AND HIGH CALCIUM LIME.

All figures are Pounds per Square Inch.
Two parts sand to 1 part slaked lime by weight.

Dolomite Lime.							High Calcium Lime.						
	4 weeks.	8 weeks.	3 months	4 months	6 months	1 year Aug. 4.		4 weeks	8 weeks	3 months	4 months	6 months	1 year May 27
	Broke placing in machine	28	42	58	90	95		32	31	40	46	57	48
		25	45	45	75	85		27	36	38	51	50	50
		35	32	43	77	80		30	39	36	24	45	42
		29	34	55	90	96		22	41	43	40	56	38
		20	40	57	83	103		32	36	......	47	57	45
		36	30	48	......	98		41	......	......	26	40	......
Av....		$28\frac{5}{6}$	$37\frac{1}{6}$	51	83	$92\frac{5}{6}$	Av.......	$30\frac{2}{3}$	$36\frac{3}{5}$	$39\frac{1}{4}$	39	$50\frac{5}{6}$	$44\frac{3}{5}$

The analysis of the dolomite limestone tested is as follows:

Calcium carbonate 54.20
Magnesium carbonate 45.06
Silica 0.45
Iron and alumina 0.275

The lime was burned from pure dolomite and although it came from several different localities the analysis does not vary more than 1 or 2 per cent. in any case.

The analysis of the high calcium limestone is very closely as follows:

Calcium carbonate 86.22
Magnesium carbonate 9.27

HYDRATED LIME.

The growing use of lime which is prepared at a factory ready for addition to mortar, and which is sold on the market under various trade names, warrants a short description of one or two of the processes of hydrating lime as examples of methods in use.

The first process described requires for rapidity and effectiveness that the lumps of quick lime be reduced to a size passing a one-inch screen by passing through a rotary or pot crusher. From bins the lime is drawn into hopper scales, in which it is carefully weighed into 1,000 to 2,000 pound batches, each batch being dumped into a hydrating pan revolving on a vertical axis. A scraper in this pan levels off the surface, making the depth of lime about 7 inches. Plows on a fixed frame turn the lime over twice in each revolution of the pan. A tank placed above

the pan is arranged to draw from supply and measure automatically the proper amount of water for the amount of lime in the pan and to discharge this amount through a sprinkler into the lime as the hydrating pan revolves under it. The plows insure that the water reaches all the lime and completely hydrates it and the heat generated in the process evaporates all excess of water and leaves the hydrated lime as fine dry powder. A hood over the pan draws off through an air shaft the steam and dust. When the lime has cooled sufficiently the discharge is opened and it is scraped out of the pan to a receiving bin, from which it goes to screens for the purpose of removing any lumps of foreign matter or unburned rock, these screens having from 40 to 200 meshes to the linear inch. In some plants this separation is made by an air-blast which carries over the fine, light particles, leaving behind the heavy and coarse materials. In some plants the lime is ground in tube mills or other grinding apparatus before it is hydrated.

Other processes use closed cylinders revolving like rotary kilns. In one such process the lime is inserted in lumps. The measured water is discharged by a sprayer upon the lumps of lime as they are tumbled about by the revolution of the cylinder. The inclination of the cylinder gradually moves the lime along to the first screen, which removes any lumps, and the final screened product is discharged hydrated and dry at the lower end of the cylinder. Through the axis of cylinder and screens passes a steam pipe with perforations on the upper side, which supplies what additional moisture is needed to complete the hydration of the lime. In some plants this cylinder is under pressure and most of the water for hydrating is introduced in the form of steam under pressure varying according to the ideas of the particular operator. The hydrating process is so new that there are as yet few generally accepted fixed ideas as to what should be standard practice.

Both high calcium and magnesian limes are used in making hydrated lime. One popular brand shows on analysis a composition of hydrated lime, 62.68 per cent.; oxide of magnesia, 32.74; silica, 3.82; and iron and alumina, 1.10 per cent.

The difficulties in the hydration of magnesian limes on the

work make this wholesale process specially acceptable for them.

The hydrated lime manufacturers have adopted the following shipping standards:

Bags.—A heavy, closely woven burlap or duck bag, containing 100 pounds; 20 bags to the ton. A paper bag containing 40 pounds; 50 bags to the ton.

Quotations.—All quotations are made including the cost of the package, no bulk quotations being made.

Returned Sacks.—The burlap or duck bags will be repurchased from the customer at ten cents each, when returned to the mill in good condition, freight prepaid.

Terms of Settlement.—A discount of 1 per cent. will be allowed for cash in ten days, the discount to be taken on the full price including the bags, f. o. b. manufacturer's plant or shipping point. Net cash 30 days.

SAND-LIME BRICKS.

A new and important application of lime is in the manufacture of bricks of lime and sand. The following from a paper by S. V. Pepple will give some idea of the materials, process and the value of the product:

Mr. Peppel proposes to restrict the term "sand brick" to combinations of sand with calcium, calcium-magnesium, or magnesium silicate, formed by the action of steam under pressure upon silica or quartz and calcium or magnesium hydrates, or a mixture of both of them. This would cut out some of the methods of hardening the brick which are described in Stoffler's "Silico-Calcareous Sandstones," but practically this is of little account, since all the practical processes use steam under pressure as the hardening agent and nearly all of them use high pressure.

A laboratory was fitted up for making briquettes for determining tensile and compressive strength of sand brick made according to various processes, and the various facts collected during the experiments are discussed under six heads.

1. *The Raw Material and Its Preparation.*—It was found that almost any sand can be forced to produce a fair product by proper variation in treatment to suit its physical and chemical properties, but there are limitations dictated by economy in manufacture and durability of product. Thus, too much clay

in the sand makes the bricks short-lived in severe weather. Comparatively pure sand is essential to cheap manufacture and fineness less than No. 20 sieve, unless sizes are well graded. The sand having the least percentage of voids is the best, other things being equal. Some experiments on a mixture of sand and pure potters' flint for fine material were made. The sand had 50 per cent. of size between 40 and 60, 7 per cent. each between 60 and 80, and 80 and 100 and 3 per cent. between 100 and 150. The flint had 3 per cent. between 100 and 200 mesh, 65 per cent. between .00212 inch and .000136 inch diameter, and 32 per cent. too fine for measurement. The results of the tests showed a decrease in crushing strength from 3,114 pounds per square inch with 8 parts of the coarse and 2 parts of the fine to 2,641 pounds with 3 parts of the coarse and 2 parts of the fine. At the same time the tensile strength was increased from 131 pounds per square inch with the former mixture to 224 pounds with the latter. These experiments simply show the desirability of tests of any proposed sand and of the determination of methods of improving it if found necessary for the best results. The control of the product by means of frequent examinations of the sand is also indicated.

The paper concludes that if a No. 40 screen is used at least one-fourth of the sand must be ground to pass through a 150 mesh, and if the sand is well graded in size an amount of the fines equal to the lime used should be added. The fines accelerate the chemical action of hardening. Closer experimentation may show more clearly the relations of sizes needed to produce the minimum of voids, and may even show as in the case of the larger materials used in Warren's bitulithic pavement, that the best result is obtained a little short of the minimum of voids if the proper sizes to omit are determined.

The effect of clay as an impurity in the sand was studied in some detail. For briquettes made under a pressure of 10,000 pounds per square inch in molding, both crushing and tensile strength decreased with an increase in the percentage of clay, being a third or more on an increase from 2.5 to 20 per cent. of clay. Under 15,000 pounds molding pressure briquettes made with double the percentage of lime showed decrease in crushing strength of one-sixth to one-third, but increase in tensile

strength of similar proportions. Increase in lime to 20 per cent. increased the strength of briquettes with two parts clay and three parts sand so that they were stronger than those of three parts coarse and two parts fine sand and five parts lime. In other words, increase in percentage of lime offset the effect of the clay. This effect was partly nullified in aging the briquettes, so that in addition to increasing the cost of bricks on account of the increase in lime the durability is somewhat effected. The paper concludes that clay up to 10 or 12 per cent. is probably not dangerous and that perhaps 2.5 per cent. might be desirable. Clay makes the molding process easier.

The effect of feldspar as an impurity in the sand is more complex and is not so serious. It deserves further study. Burnt clay used in place of fine sand cuts the compressive strength in two. The amount of lime to be used was tested. Doubling the amount of dolomitic lime increased the strength 50 per cent. Multiplying the proportion of lime by 8 multiplied the strength by 2.5. The increase is not in proportion to the increase in cost. The common practice of using not more than 10 per cent. of lime is commended, provided the sand is clean.

The difference in value of gray lime made from limestone having 85 per cent. or more of calcium carbonate and of white lime made from dolomitic limestones nearly half carbonate of magnesia was tested, the results showing, with 10 per cent. of lime in the brick mixture, a strength of the bricks with pure lime 50 per cent. greater than that of bricks made of the magnesian lime.

In preparation of the sand it may be necessary to crush soft sand rock, to dry at least partially sand obtained by dredging, to wash out clay or soluble salts and in some cases to grind part of the sand very fine in ball, tube or Griffin mills. Some foreign manufacturers roast the sand, but the utility of the process is not well settled.

The lime must be slaked either before or after mixing with the sand, the time required to slake dolomitic lime demanding the former. Most of the patents on sand brick are on methods or machines for slaking lime and mixing with the sand and utilizing the heat generated in the process. The paper suggests

several methods of manipulating the mixture of the two materials.

2. *Behavior of the Mixture in the Press.*—Experiments were made with bricks made by mixing dry sand and ground lime to determine the most suitable pressure for compressing the bricks with the result that 15,000 pounds per square inch produced stronger briquettes than either greater or less pressures. The behavior of the blocks in the press is also considered in the paper.

3. *Hardening.*—The tests on this process showed that at 150 pounds steam pressure the maximum hardening effect was produced in about 4 hours, that at 120 pounds 6 to 8 hours' time is necessary, and at 100 pounds 8 hours or perhaps more. The usual practice of using 120 pounds pressure for 8 to 10 hours is commended.

Testing.—Fractures under crushing loads are like those in hard stone. Cubes frozen and thawed twenty-one times in succession showed actual increase in strength, due perhaps to hardening action of carbonic acid in the water used to thaw the blocks. Samples made of pure sand stood about 2,300 degrees F. of heat in muffle. Those containing clay or feldspar exploded before reaching high temperatures. Absorption of water was about 8 to 10 per cent. in forty-eight hours, usually nearer the lower limit. The paper gives a comparison of sand brick with averages of natural sandstone from Wisconsin, showing practically the same weight, 136 pounds a cubic foot absorption, 10 per cent. greater in sand brick. Crushing strength, 7,745 pounds per square inch for sand brick as compared with 6,535 pounds for the sandstone, coefficient of elasticity say four times as great, being 600,000 for sand brick.

5. *Mechanical Equipment.*—Under this heading the paper considers the mixing apparatus, including edge runners, wet and dry pans, pug-mills of various sorts and the Schwartz system, which controls the amount of moisture; lime-preparing machinery; presses, including the Kahl and Komnick, expressly designed for sand brick, and the American dry-press brick machines which have been applied; hardening cylinders; tracks and trucks.

6. *Discussion of the Merits of Systems.*—Five processes or

systems are considered including the Komnick, Kleber, Brown, Schwarz and Huennekes.

The process of hardening with steam under pressure was invented by Dr. Michaelis, and has been presented to the public. There are several patents in this country which actually cover special methods of applying the process only.

Under nine of the patents good bricks can be made, and by five of them the author thinks the cost of making brick under the same conditions would not vary more than 35 cents a thousand. The cost of plants varies according to local conditions. A plant to make 20,000 bricks in ten to twelve hours would cost in Ohio, without real estate, $20,000 to $25,000. The cost of production, not including depreciation and interest on investment, varies from $3.50 to $5 per thousand, and the selling price ranges from $8 to $15 in various localities.

GYPSUM PLASTER.

Plaster of paris or stucco is made from gypsum by a process described below. There are many deposits of the material in this country, in New York, Ohio, Pennsylvania, Virginia, Iowa, Kansas, Arkansas, Oklahoma, Texas, Colorado, Wyoming, Nevada, California, Michigan, etc. Several deposits in Kansas, Texas and elsewhere are composed of gypsum and earthy materials, which are excavated in form for the final pulverizing or for direct discharge into the calcining kettles. The name gypsite has been proposed for this material. The product has been named cement plaster. On account of the other ingredients in it this cement plaster does not require the addition of much, if any, material to retard its setting and is otherwise subject to some variations in treatment from the product of mills using pure gypsum. The following description of the processes of preparing gypsum and gypsite and making stucco and cement plaster is prepared from two articles, one by Paul Wilkinson and the other by W. R. Crane.

Gypsum rock, as is well known, occurs in ledges, is mined and transported to the factory, and there reduced by nippers and Gates crushers to the size of small marbles. It is then run through buhrs and finely ground, and conveyed by elevators to bins over the calcining kettles. From this stage the process is practically identical with the manufacture of gypsite into cement plaster. Gypsite occurs in pockets of greater or less

extent on the surface of the earth, with from a few inches to 2 or 3 feet of surface loam on top. It resembles marl in appearance, and is in a fine state of subdivision. It is usually more or less moist, on account of the fact that the pockets occur in marshy meadow lands along the sides of a stream. In mining it the surface covering is stripped off and scraped to some distance outside the deposit. It is most advantageously manufactured during the hot season of the year, as at that time manufacturers obtain the assistance of nature in drying out the physically combined moisture. It is a peculiarity of gypsite that it absorbs and holds water with great avidity and freezes readily, so that in securing stock for winter purposes it is necessary to have large storage sheds and fill them during the drier months of the year. The material is frequently piled in various portions of the bed to mix the various strata thoroughly, as well as to permit the moisture to drain out.

The material is loosened in the deposit by means of disk harrows and then taken into the stock warehouse by means of wheeled scrapers. There are some irregularities in every deposit; and the principal object sought by the manufacturer is to mix the materials thoroughly, so as to procure a uniform output. After the material has been put in the warehouse it is at the same stage as the plaster of paris when the latter has reached the bins, as above described.

The principal and really exact process is that of calcination. For this purpose boiler-iron kettles of 5/8-inch thickness, 8-feet diameter and 6-feet depth are used. The foundation for a kettle is necessarily built very solid, the fire space within the foundation being in the shape of an inverted truncated cone 4 feet high. At the top of this a cast-iron flanged ring is set into the masonry. The kettle bottom, consisting of a concave-convex iron casting a little less than 8 feet in diameter, with convexity placed upward with a rise of 1 foot, and with a thickness of 3/4 inch at the edges and of 4 inches at the crown, is set within the flange at the top of this ring. The kettle proper is then placed over the kettle bottom. This kettle has two flues 12 inches in diameter, placed transversely about 8 inches above the crown of the kettle bottom, and separated externally about 6 inches. After the kettle has been set brick masonry is erected around it, gradually converging at the top to meet the top rim of the kettle. The first floor of each mill is usually built around the kettle about a foot from the top, sometimes level with the top, to facilitate the shoveling of dirt directly into the kettle by hand; and the kettle, with the furnace, is in the basement, with storage room for fuel conveniently arranged in front of the kettle. Ports are made through the side of the base ring.

and the heat from the furnace is deflected by bridges around the surface of the kettle, so that it may cover every part of the kettle, pass through the flues, and finally make exit through a regular stack. For fuel, the best of coal must be used, having a minimum of sulphur, coking freely and giving a long flame. The best coal is procured in the Trinidad district of Colorado. Kettle bottoms of sheet steel have been tried, but do not serve as well as cast-iron ones. Only the best scrap iron must be used in these kettle bottoms, it having been found that ordinary scrap iron does not last nearly so long as pig. The life of a kettle bottom is terminated by cracking. The cracks can be caulked with asbestos cement, but the expense of repairing and stoppage soon overcomes the saving. At the top the kettle is covered with a sheet iron cap with a movable door, through which the material is introduced, usually by a chute, fed by an elevator from the dirt pit. The usual number of kettles is four to six. They are arranged in line and usually worked in pairs. It is necessary that the material in the kettle be constantly agitated; and for this purpose a line-shaft is run over the kettles and a vertical shaft runs from this to the bottom of each kettle, being supported below by a saddle placed between the flues. At the bottom of the shaft a curved cross is attached, to which are affixed movable teeth with paddles, which are so adjusted as to throw the material from the periphery to the center. Should the agitation stop or the teeth become broken, the material settles down on the bottom, and, owing to the intense heat, the bottom is almost instantly melted through. The material when heated is very fluid, runs through like water and quenches the fire.

Both water power and steam power are used for driving the machinery. When steam is used the slack from the fuel used under the kettles is employed for the boilers.

Upon the correct calcination, more than anything else, depends the quality of the material. The calcium sulphate in gypsite is hydrated, as it is in gypsum rock. The object sought is to drive off a portion of this water of crystallization. To attain this end, in the plaster of paris manufacture, the temperature of the kettle, starting at 212 degrees, rises to 350 degrees F., when it is drawn off and a new charge placed. At the temperature of 230 degrees and 280 degrees F., the mass is boiling actively, while at the intermediate temperature of 270 degrees it is solid.

In the manufacture of gypsite, probably on account of the foreign matters, a higher temperature is required, which averages close to 396 degrees F. In starting a kettle, heat is gradually applied, and the crude material is gradually fed in and

constantly agitated. This process is slow, and requires some length of time on account of the vast amount of physically combined moisture to be evaporated. Material is gradually added until the kettle is full, and during this process the contents of the latter boil in a violent manner, closely resembling the boiling of water. The fact that the physically combined moisture is all evaporated is indicated by the prompt settling of the material; the heat then rises to a higher degree and ebullition again takes place, indicating the driving off of the water of crystallization. The point at which the process is complete is known by the manner in which the material boils and by its general appearance; and the calciner, at the proper moment, lets off the charge through a small gate at the bottom and in the side of the kettle. Thermometers are used in plaster of paris manufactories to govern the temperature exactly; but in the gypsite manufactories the point varies slightly and is usually best known by an experienced calciner. The escaping steam is let off by means of a stack let into the sheet iron cover of the kettle parallel with the smokestack, and this stack contains near its base a separator similar to the steam separators for the purpose of retaining the plaster dust. It has been found by raising the iron cover about 18 inches and putting on proper sides that it furnishes a chamber above the boiling material and greatly assists the escape of the steam from it.

From the kettle the hot material runs like water into a fireproof pit. The kettles are usually run in couples so that one pit will do for two kettles; and one chute will do for two kettles in filling, as the kettles are run at slightly different periods. Each kettle contains a charge of about five tons of manufactured material, and requires about three hours to calcine properly. After cooling slightly the manufactured material is elevated into a revolving screen, which separates all small particles and foreign matter, and renders the product uniform. The screenings run from ½ to 1 per cent. only. It is usual to have a series of screw conveyors and elevators both in front of and behind the screen, so as to mix the material thoroughly. Owing to the temperature of the material, all conveyors, elevators and interior linings must be of metal, and the screen is made of wire cloth. From the screen the material is conveyed to the storage bins, which are usually arranged to hold 100 or 200 tons, and of which there are several, so as to separate, if desired, the runs of different days. The material is usually allowed to fall from a screw at the top of the building, first that it may spread out and let the different portions mix thoroughly, and, secondly, that it may cool in passing through the air.

In some of the more recently constructed mills the products,

both before and after treatment, are handled mechanically. The car of rock is trammed by hand or drawn by horse to the foot of an incline, up which it is drawn by cable, dumped and returned to the foot of the incline.

Several forms of conveyors, such as the belt, screw and bucket types, are employed, which combined with gravity spouts and launders do away with a great deal of manual labor.

A new departure in the method of elevating the flour gypsum is the air blast, by means of which the finely ground mineral is raised to any desired height. Although the method is not viewed with favor by some operators, it is quick, neat and economical and can frequently be employed more advantageously than an elevator.

The following outline will give an idea of the general method of treatment:

Gypsum rock from mine to crusher	to	(1)
Gypsum earth from mine to crusher	"	(2) or (3)
(1) Crusher reducing to 2 and 4 in. sizes	"	(2)
(2) Gates crusher reducing to .25 and .5 in sizes	"	(3)
(3) Elevator	"	(4)
(4) Bin on second floor, thence by spout	"	(5)
(5) Buhr Mill, or Steel flour mill rolls, or Carr disintegrator } reducing to flour	"	(6)
(6) Elevator or blower	"	(7)
(7) Storage bin on second floor, just over kettle	"	(8)
(8) Calcining kettle	"	(9)
(9) Fireproof bin on ground floor	"	(10)
(10) Blower	"	(11)
(11) Bin in attic, thence by gravity spouts	"	(12)
(12) Bolting cloths, and sized, thence	"	(13)
(13) Mixer by gravity spouts	"	(14)
(14) Boxing and barreling department.		

A number of French furnaces have been recently devised for producing a plaster which shall be normally dehydrated and white, and at the same time cheap. One of these consists of a heating furnace and a baking chamber; the furnace, heated by coke or other smokeless combustible, communicates by a conduit with the chamber, which is formed of a metallic cylinder revolving about its axis upon mechanically operated rollers, and contains the pulverized gypsum, which rolls upon itself by the continuous movement of the drum, so that its particles are successively exposed to the hot gases which traverse it. Above the drum is the charging-bin, in which the gypsum is heated previous to its introduction, being surrounded by a series of tubes which are heated by the discharge gases. When one charge is baked it is let fall into the lower chamber by a

trap, and a new supply fed in from the charging hopper. The latter is kept supplied from the grinding mills by a bucket conveyor.

There are many proprietary plasters on the market which claim special advantages for various classes of work. Most of them keep secret the ingredients added to the plaster of paris base. Alabastine, plasticon, King's Windsor cement, made of plaster and asbestos, adamant wall plaster, kallolite cement plaster, paragon, Old Roman, zenith and Samson are some of the trade names for cement and wall plasters.

Sanded plaster fully prepared and mixed by machinery at the mill where the plaster is made is sold by some manufacturers. The advantages claimed as an offset for the payment of freight on the sand in the mixture are purity of sand, correctness of proportions and thoroughness of mixing and consequent greater uniformity.

Plaster is shipped in paper bags, which add 2 cents to the price of the plaster, or in jute bags at 10 cents, the jute sacks being subject to return in good condition at the same price, less the return freight on the shipment of sacks. Paper sacks of plaster weigh 80 pounds; jute sacks, 100 pounds.

Selenitic cement is a mixture of lime with a small quantity (less than 10 per cent.) of plaster of paris.

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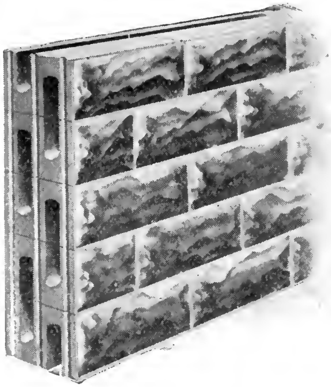
THE BLAKESLEE BLOCKS



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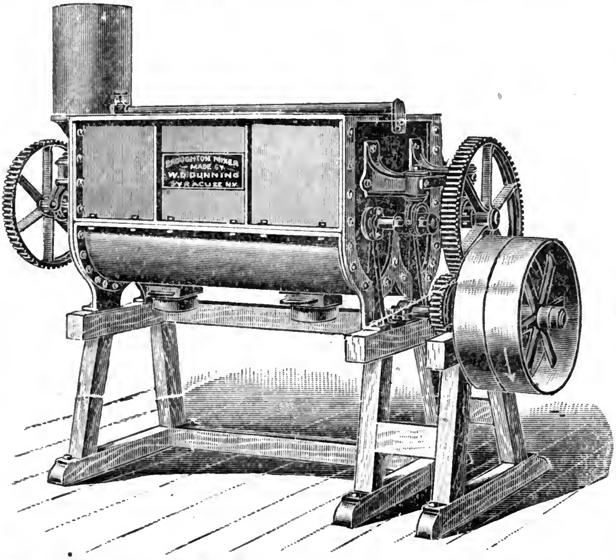

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